GBP

GRASSLAND BYPASS PROJECT

2000-01

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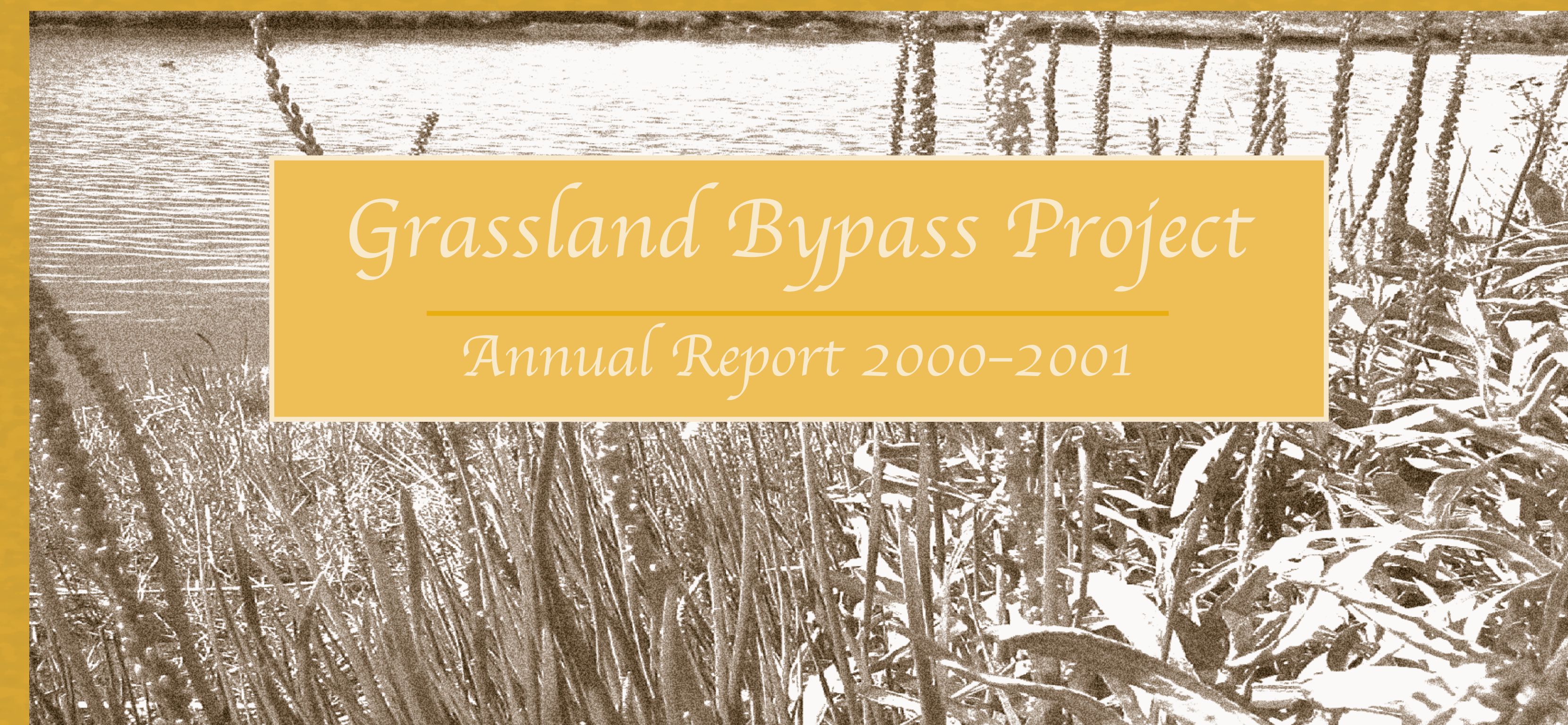


Grassland Bypass Project

Annual Report 2000–2001

Prepared by the San Francisco Estuary Institute
for the Grassland Bypass Project Oversight Committee

Grassland Bypass Project

Prepared by SFEI for the Grassland Bypass Project Oversight Committee

U.S. Bureau of Reclamation
U.S. Environmental Protection Agency
U.S. Fish and Wildlife Service
U.S. Geological Survey
Central Valley Regional Water Quality Control Board
California Department of Fish and Game
San Luis & Delta-Mendota Water Authority

Grassland Bypass Project

GRASSLAND BYPASS PROJECT

1 Summary

Bob Young, Technical Team Leader
U.S. Bureau of Reclamation

Introduction

The Grassland Bypass Project (GBP) completed its fifth year of operations on September 30, 2001. This annual report documents results from the monitoring efforts for the fifth year (water-year (WY) 2001). Information from the previous four years are included where appropriate. One function of the annual report is to document results from the multi-agency data collection effort. The report builds upon previous information allowing for the discernment of changes in environmental conditions over time.

During the year, the Data Collection and Reporting Team (DCRT) continued to meet and review project data and associated reports. The following reports were reviewed and published during the final program year: monthly reports (12), quarterly data reports (4), graphical and narrative summaries (4), and the 4th annual report.

This annual report consists of technical chapters prepared by the agency staff responsible for their data collection effort within the GBP monitoring program.

Project Authorization

The U.S. Bureau of Reclamation (USBR) signed a Finding of No Significant Impact (FONSI) on November 3, 1995 for use of a 28-mile segment of the San Luis Drain (SLD) (USBR, 1995). This segment conveys agricultural drainage waters from the Grassland Drainage Area (GDA) to the San Joaquin River via a 6-mile segment of Mud Slough (North). A map of the GBP area and a schematic diagram are presented in Figures 1 and 2. Analysis from an environmental assessment (EA) dated April 1991, and supplemented in November 1995, resulted in the FONSI.

A Use Agreement (UA) was also signed on November 3, 1995 between USBR and the San Luis & Delta-Mendota Water Authority (SLDMWA) (USBR and SLDMWA, 1995). The UA provided the terms and conditions for the use of the SLD. The UA allowed for renewal of the interim two-year use for no more than three years if certain conditions were met. On January 25, 1999, the Oversight Committee recommended that the UA be extended until September 30, 2001.

The EA documents commitments made by participating agencies to address environmental benefits and risks. These commitments include the following:

- To ensure that progress continues toward long term resolution of agricultural subsurface drainage management activities,
- To ensure that there are no significant adverse effects to fish and wildlife, other environmental resources, and public health, and
- To ensure that the above listed commitments are implemented and addressed as part of the Project.

The EA also documented benefits and risks. The benefits include the following:

- Agricultural subsurface drainage water is removed from the Grassland Water District (GWD) delivery channels allowing refuge managers to receive and apply all of their fresh water allocations according to optimum habitat management schedules.
- Removal of agricultural subsurface drainage water from the GWD channels reduces the selenium exposures to fish, wildlife, and humans in the wetland channels and Salt Slough.
- Combining agricultural subsurface drainage flows within a single concrete-lined structure allows for effective concentrated monitoring leading to detailed evaluation and effective understanding of drainage flows and associated selenium loads.
- The establishment of an accountable drainage entity provides the framework necessary for responsible watershed management in the Grassland Basin.

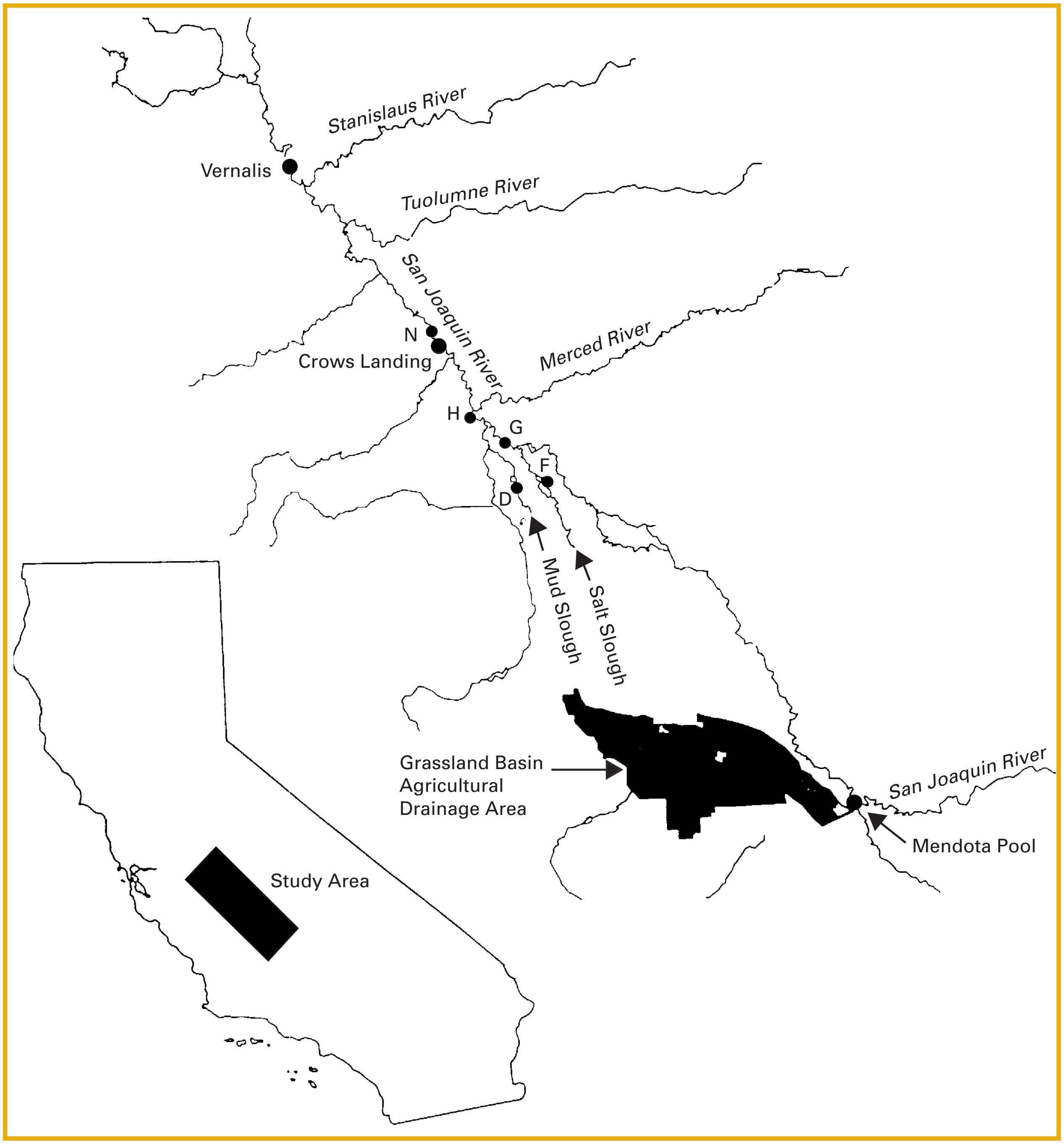
The documented risks included the following:

- Combining agricultural drainage flows within the SLD results in an increase in selenium and other constituents which are discharged into Mud Slough (North). These constituents will be above the levels historically discharged to Mud Slough (North) and could have an adverse environmental effect on six miles of Mud Slough (North).
- Agricultural drainage flows will enter wetland channels during floods.

2000-2001 Highlights

During water year 2001, monthly selenium loads discharged from the terminus of the SLD were all below the load values agreed upon in the UA (Figure 3a, Tables 1 and 2). The annual discharge amount, 4,377 pounds, was 23 per cent below the annual load value, 5,661 pounds. For comparison purposes, monthly discharges are also provided for water years 1997, 1998, 1999 and 2000 (Figures 3b, c, d and e).

Figure 1. Map of the Grassland Bypass Project



Completed Reports for the Continuation of the Grassland Bypass Project

1. Final Environmental Impact Statement and Environmental Impact Report for the Grassland Bypass Project, May 25, 2001
2. Biological Assessment, Grassland Bypass Project, 2001-2009, February 2001
3. Biological Opinion for the Grassland Bypass Project, September 27, 2001
4. Record of Decision, Grassland Bypass Project, September 28, 2001
5. Waste Discharge Requirements, No. 5-01-234 for San Luis & Delta Mendota Water Authority and the USBR, for the Grassland Bypass Project, September 21, 2001
6. Agreement for Use of the San Luis Drain, October 1, 2001 through December 31, 2009, September 28, 2001
7. Final Fish and Wildlife Coordination Act Report for the Grassland Bypass Project, December 28, 2001
8. Update of Long-Term Drainage Plan, December 31, 2001

Additional Reports/Studies

1. "Sources of Selenium" studies

Heavy rainfall during the first two Project years resulted in selenium load discharges exceeding load values. On-farm management activities were not able to control the excessive rainfall and associated storm runoffs through project boundaries. As a consequence, discharges through the San Luis Drain, and in some cases wetland channels, were above what were planned. The Oversight Committee recommended that additional studies be undertaken to establish the sources of selenium. Numerous studies are being worked on by the USGS, LBL, CVRWQCB, and USBR.

2. CVRWQCB draft staff reports

a. "Agricultural Drainage Contribution to Water Quality in the Grassland Watershed of the Western Merced, California, October 1999-September 2000 (WY2000)"

b. "Water Quality of the Lower San Joaquin River: Lander Avenue to Vernalis: October 1999 - September 2000 (WY 2000)" The two CVRWQCB technical reports document the water quality measurements for WY 2000. Comparable annual data reports for have been published by the CVRWQCB since 1986.

Monitoring Program

The monitoring plan outlines the processes for collecting data to determine if the terms and conditions of the GBP are being met. Flow, water quality, sediment, biota, and toxicity data are collected to assess the Project impacts (Table 3). The data gathered from this effort allow evaluation of the degree to which the commitments of the UA, 1991 EA, 1995 Supplemental EA, FONSI, and Appendix A of the UA are being met.

Changes were made to the GBP monitoring program during the year. Those changes are documented within each of the following technical chapters. The major change included the relocating sampling Site I to I2 in March, 2001 (see Chapter 7 for details).

Water Quality Monitoring on the San Joaquin River at Hills Ferry

As reported in the 4rd Annual Report, the CVRWQCB dropped the Hills Ferry water quality sampling station. Since the station is used for biological monitoring, an agreement was worked out between USFWS and SLDMWA to continue water quality monitoring in order to aid potential future development of revised criteria. The SLDMWA agreed to perform the

PARAMETER	Specific Conductance	Selenium (total)	Boron
DATA SOURCE	SLDMWA	SLDMWA	SLDMWA
UNITS	µS/cm	µg/L	mg/L
Sep-01-2000	1,520	8.1	1.5
Sep-08-2000	1,580	8.2	1.8
Sep-13-2000	1,250	5.3	1
Sep-21-2000	1,560	6.9	1.3
Oct-04-2000	NT	5.3	NT
Oct-12-2000	1,010	2.6	0.8
Oct-18-2000	1,150	2.2	0.8
Oct-26-2000	1,310	2.4	0.9
Nov-02-2000	836	1.3	0.8
Nov-10-2000	1,410	4	1.1
Nov-12-2000	1,850	4.3	1.3
Nov-17-2000	1,760	4.4	1.3
Nov-22-2000	1,850	4.3	1.3
Nov-30-2000	1,820	4	1.4
Dec-08-2000	1,720	3.3	1.7
Dec-14-2000	1,780	3.3	1.3
Dec-21-2000	1,840	4.3	1.3
Dec-28-2000	2,000	4	1.5
Jan-04-2001	2,120	3.7	1.5
Jan-09-2001	1,830	3.4	1.3
Jan-16-2001	1,630	2.7	1.2
Jan-24-2001	2,020	3.6	1.5
Jan-30-2001	1,700	4.1	1.3
Feb-06-2001	2,150	6.3	1.6
Feb-13-2001	1,790	6.6	1.4
Feb-20-2001	2,020	7.6	1.6
Feb-27-2001	1,350	4.9	1
Mar-06-2001	1,360	4.3	1.1
Mar-13-2001	1,690	5.7	1.4
Mar-20-2001	2,210	8.1	1.9

Figure 2. Schematic Diagram Showing Locations of GBP Monitoring Sites Relative to Major Hydrologic Features of the Study Area

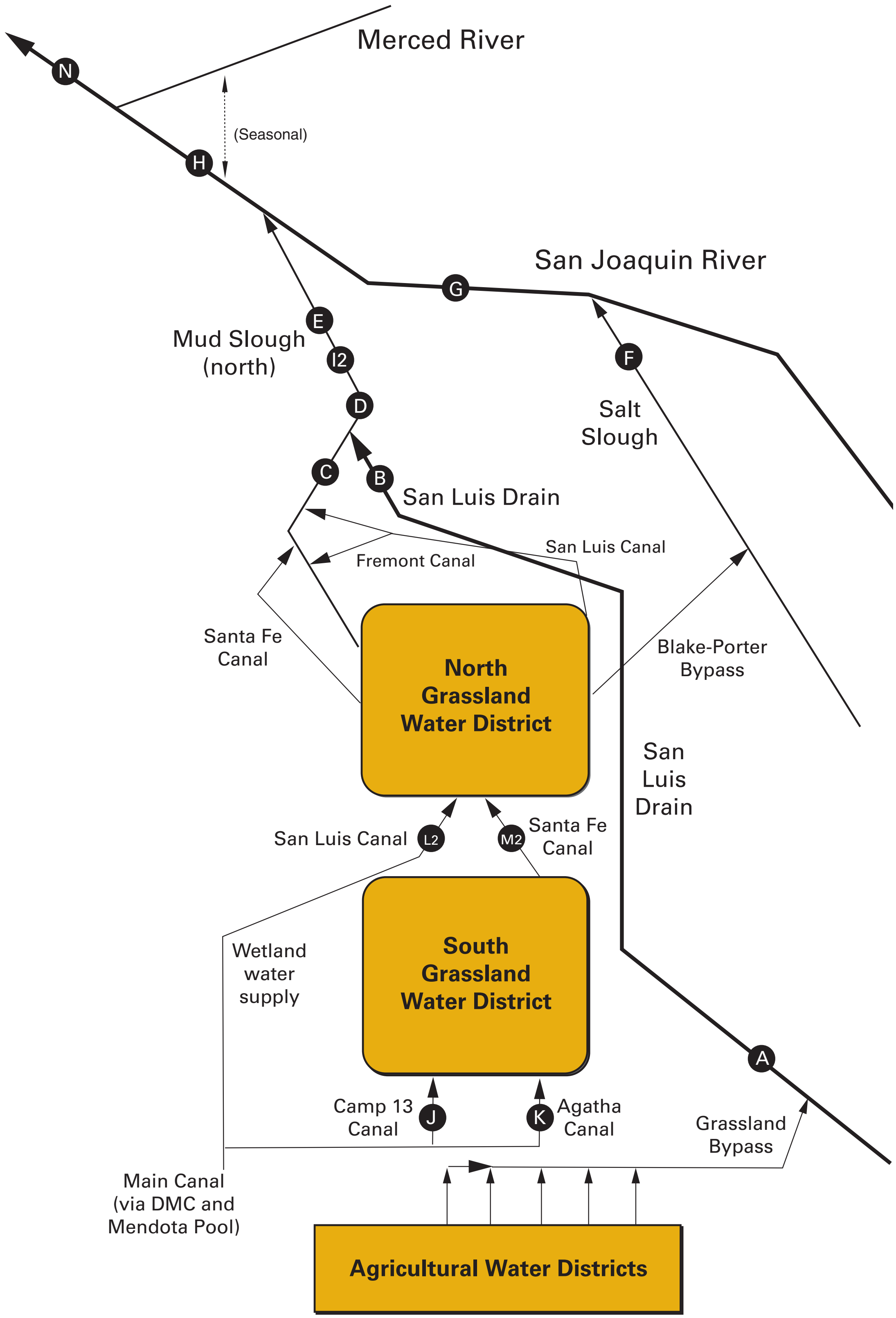


Table continued from previous page

PARAMETER	Specific Conductance	Selenium (total)	Boron
DATA SOURCE	SLDMWA	SLDMWA	SLDMWA
UNITS	µS/cm	µg/L	mg/L
Mar-27-2001	2,140	7.1	1.8
Apr-03-2001	2,430	9.6	1.9
Apr-11-2001	1,890	6	1.5
Apr-17-2001	2,290	8.7	1.6
Apr-24-2001	1,340	5.3	1
May-04-2001	2,770	10.5	1.9
May-08-2001	2,350	8	1.7
May-15-2001	1,610	6.2	1.3
May-22-2001	2,210	6.7	1.8
May-29-2001	2,000	7.9	1.6
Jun-05-2001	1,860	9.6	1.8
Jun-12-2001	2,570	12.4	2.6
Jun-19-2001	2,020	9.3	1.8
Jun-28-2001	1,740	8.4	1.7
Jul-06-2001	2,080	9.2	2.1
Jul-10-2001	1,960	10	2
Jul-17-2001	1,900	8.3	1.9
Jul-24-2001	1,750	8.9	1.7
Jul-31-2001	1,720	8.2	1.7
Aug-07-2001	1,950	9.9	2.1
Aug-14-2001	1,990	8.7	1.8
Aug-21-2001	1,700	7.1	1.6
Aug-28-2001	1,780	8.7	1.5
Sep-04-2001	2,200	10.4	1.8
Sep-11-2001	2,030	8.3	1.3
Sep-18-2001	2,350	7.5	1.4
Sep-25-2001	2,140	4.6	1.2

NT = not tested

sampling. Starting in September 2000, the SLDMWA performed the weekly water quality sampling.

Listed below are the data for the 5th project year.

Project Organization

The GBP involves the coordination and cooperation of several State and Federal agencies whose authority, interests, or activities directly overlap in one or more aspects of the GBP. These agencies include USBR, USFWS, USGS, USEPA, CVRWQCB, CDFG and the SLDMWA. The latter organization includes local drainage and water districts that participate in the drainage activities. The Grassland Area Farmers (GAF) formed a regional drainage entity under the umbrella of the SLDMWA.

Oversight Committee (OC)

The Oversight Committee is comprised of senior level representatives from USBR, USFWS, CDFG, CVRWQCB, and USEPA. The role of the OC is to review process and assure performance of all operations of the GBP as specified in the Use Agreement, including

Figure 3a. Grassland Bypass Project Water Year 2001 Monthly Selenium Discharges into Mud Slough (Station B) Compared to Load Values

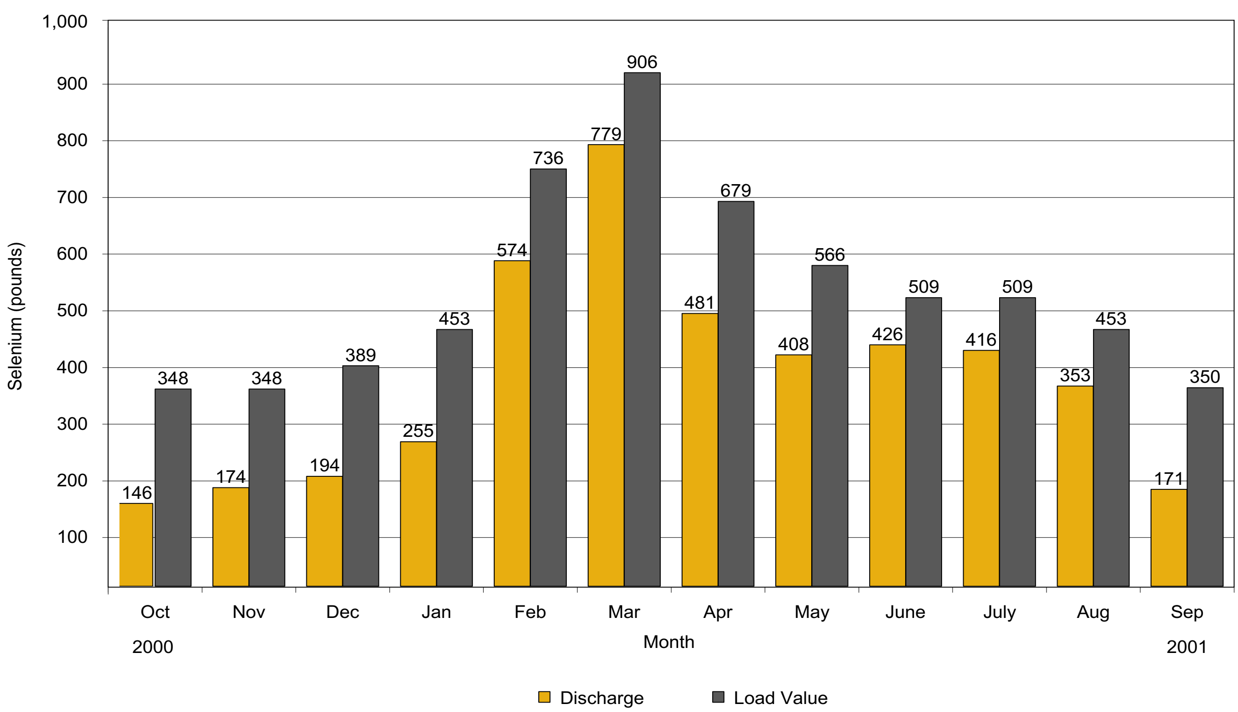


Figure 3b. Grassland Bypass Project Water Year 2000
Monthly Selenium Discharges into Mud Slough (Station B) Compared to Load Values

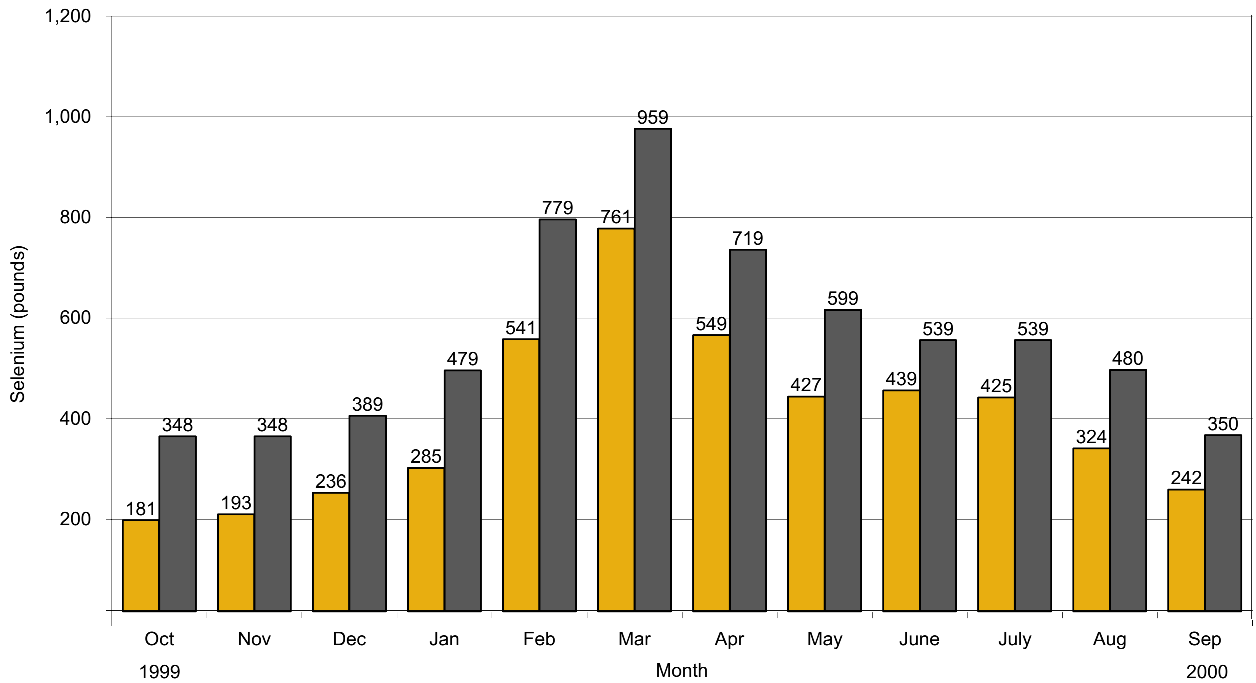


Figure 3c. Grassland Bypass Project Water Year 1999
Monthly Selenium Discharges into Mud Slough (Station B) Compared to Load Values

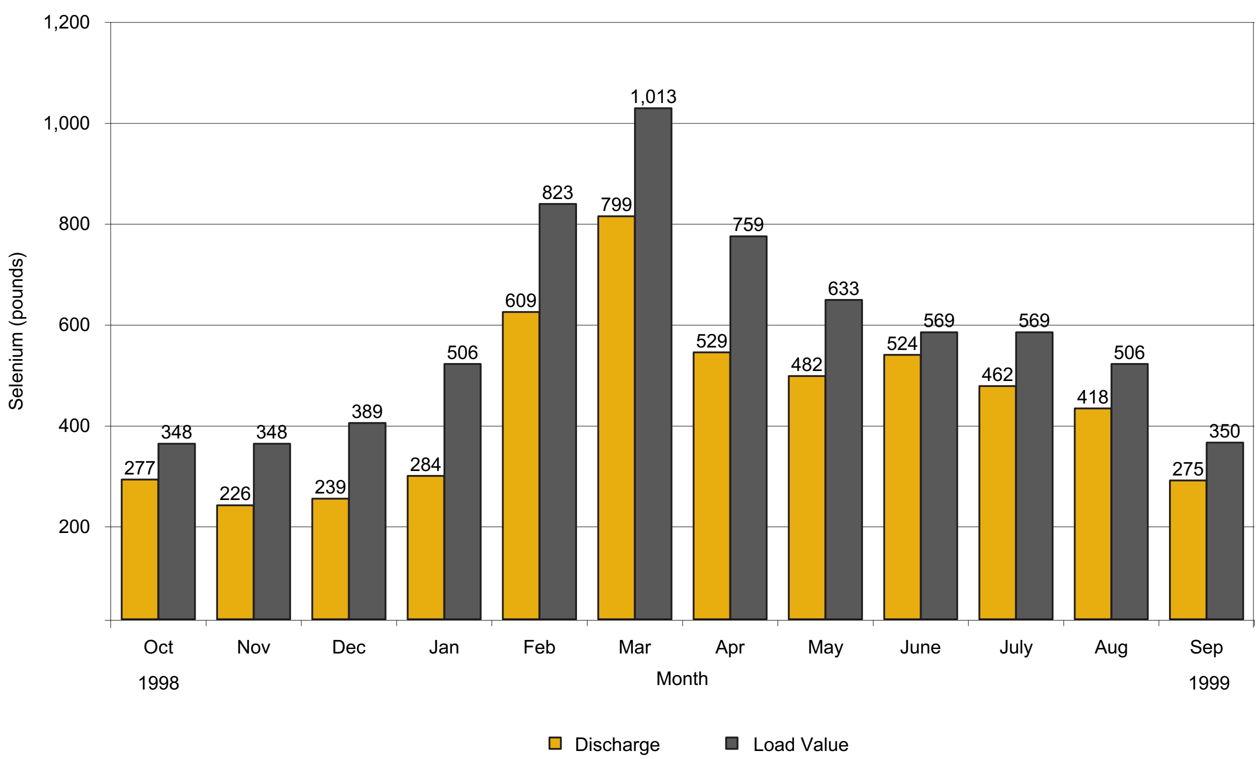
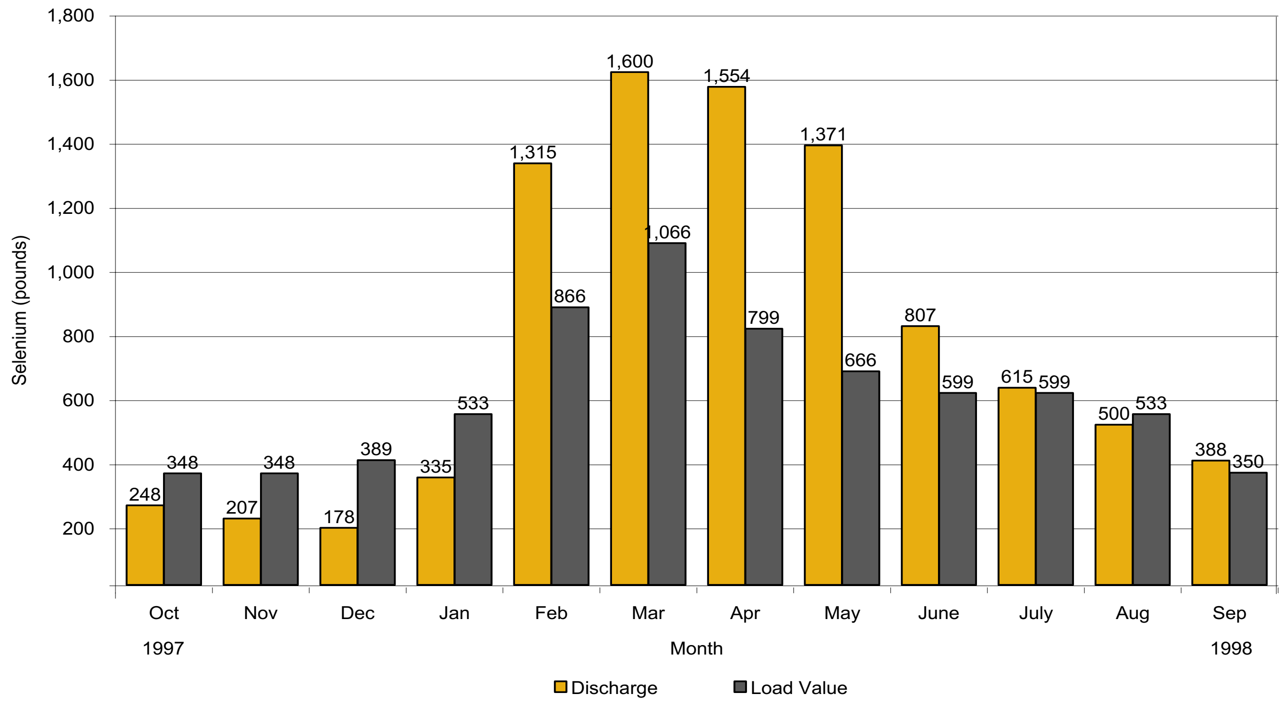
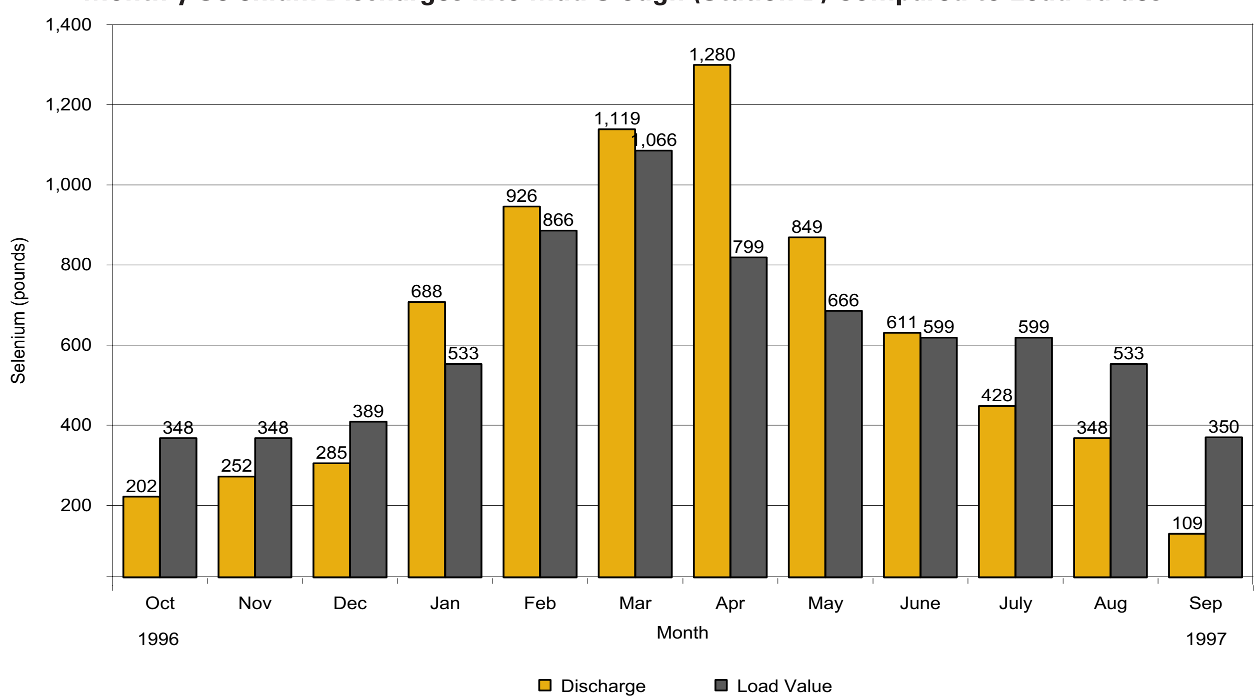


Figure 3d. Grassland Bypass Project Water Year 1998
Monthly Selenium Discharges into Mud Slough (Station B) Compared to Load Values



Note: February value includes 350 pounds of selenium discharged through wetland channels due to storm

Figure 3e. Grassland Bypass Project Water Year 1997
Monthly Selenium Discharges into Mud Slough (Station B) Compared to Load Values



Note: January value includes 89 pounds of selenium discharged through wetland channels due to storm events
Note: February value includes 48 pounds of selenium discharged through wetland channels due to storm events

Table 1. Monthly Selenium Discharges into Mud Slough (Station B) Compared to Load Values, Pounds, Water Years 1997, 1998, 1999, 2000, 2001

Month	WY 2001 Discharge	Year 5 Load Values	WY 2000 Discharge	Year 4 Load Values	WY 1999 Discharge	Year 3 Load Values	WY 1998 Discharge	Year 2 Load Values	WY 1997 Discharge	Year 1 Load Values
October	146	348	181	348	277	348	248	348	202	348
November	174	348	193	348	226	348	207	348	252	348
December	194	389	236	389	239	389	178	389	285	389
January	255	453	285	479	284	506	355	533	688 **	533
February	574	736	541	779	609	823	1,315 *	866	926 ***	866
March	779	906	761	959	799	1,013	1,600	1,066	1,119	1,066
April	481	679	549	719	529	759	1,554	799	1,280	799
May	408	566	427	599	482	633	1,371	666	849	666
June	426	509	439	539	524	569	807	599	611	599
July	416	509	425	539	462	569	615	599	428	599
August	353	453	324	480	418	506	500	533	348	533
September	171	350	242	350	275	350	388	350	109	350
12-month total	4,377	NA	4,603	NA	5,124	NA	9,118	NA	7,097	NA
Annual load value	NA	5,661	NA	5,994	NA	6,327	NA	6,660	NA	6,660

* includes 350 pounds of selenium discharged through the wetland channels due to storm events
** includes 89 pounds of selenium discharged through the wetland channels due to storm events
*** includes 48 pounds of selenium discharged through the wetland channels due to storm events

Table 2. Grassland Bypass Project Selenium Load Levels (lbs)

Month	Year 1-2	Year 3	Year 4	Year 5
October	348	348	348	348
November	348	348	348	348
December	389	389	389	389
January	533	506	479	453
February	866	823	779	736
March	1,066	1,013	959	906
April	799	759	719	679
May	666	633	599	566
June	599	569	539	509
July	599	569	539	509
August	533	506	480	453
September	350	350	350	350
12-month total[1]	7,090	6,813	6,528	6,246
Annual load Levels	6,660[2]	6,327[3]	5,994[4]	5,661[5]

1. The 12-month total for any given year is somewhat higher than the annual load target for that year because the monthly targets for the months of September, October, November and December have been adjusted to allow for greater selenium discharge than would typically occur. This adjustment has been made to provide greater selenium management flexibility during months when the assimilative capacity of the river is sufficient to sustain this greater load.

2. The annual 2nd year load target is based on the average annual loads discharged over a 9-year historical period (1986-1994) which includes both wet and dry year data, as well as full and partial water supply data. It is divided by month based on the average historical distribution of selenium loads except where the Total Maximum Monthly Load (TMML) calculation (using a 1-in-5 month violation rate) allows for a greater monthly load.

3. The 3rd year annual load target is based on a 5% reduction of the average historical loads. The 5% reduction is applied equally across all months except where the TMML (using a 1-in-5 month violation rate) allows for greater monthly selenium loads.

4. The 4th year annual load target is based on a 10% reduction of the average historical loads. The 10% is applied equally across all months except where the TMML (using a 1-in-5 month violation rate) allows for greater monthly selenium loads.

5. The 5th year annual load target is based on a 15% reduction from the average historical load. The 15% is applied equally across all months, except where the TMML (using a 1-in-5 month violation rate) allows for greater monthly selenium loads.

Table 3. Monitoring Stations, Parameters, and Frequencies

STATION		PHYSICAL					CHEMICAL		SEDIMENT	BIOTA	CHRONIC TOXICITY
		Flow	Temp	pH	EC	TSS	Se	B	Bed Se	Se	
San Luis Drain	A	C	C	W	C	W	W	W	Q		
	B	C	C	W	C	W	D	W	Q		M
	checks 1-2								A		
	checks 10-11								A		
	checks 14-15								A		
	checks 17-18								A		
Mud Slough	C		W	W	W		W	W	Q	Q	M
	D	C	C	W	C		W	W	Q	Q	M
	E								Q	Q	
	I2		A	A	A		Q	Q	A	Q	
Salt Slough	F	C	C	W	C		W	W	Q	Q	M
Wetland Channels	J	D	W	W	W		W	W			
	K	D	W	W	W		W	W			
	L2	D	W	W	W		W	W			
	M2	D	W	W	W		W	W			
San Joaquin River	G		W	W	W		W	W		Q	
	H									Q	
	N	C	C	W	C		D	D			

KEY
C = continuous
D = daily
W = weekly
M = monthly
Q = quarterly
A = annually

monitoring data, compliance with selenium load reduction goals, and other relevant information.

The OC meets in a public forum, as needed, to review the status, progress, and monitoring results of the GBP. The OC considers findings and recommendations from the TPRT and other subcommittees. The OC also considers input and recommendations from the SLDMWA and other key stakeholders.

Technical and Policy Review Team (TPRT)

The Grassland Bypass Project Oversight Committee formed the TPRT to serve as staff to the OC. The TPRT consists of a representative from CVRWQCB, CDFG, USBR, USFWS, and USEPA, plus a member from USGS serving as an independent technical advisor. The TPRT is responsible for obtaining and providing the necessary information, developing alternatives, and formulating recommendations to the OC. This includes producing, or overseeing the production of any analytical and interpretive reports, other than the normal monthly, quarterly, and annual reports, and obtaining appropriate peer or scientific review as necessary. The TPRT is responsible for coordinating, evaluating, and recommending associated research and investigation needs as the GBP proceeds. The TPRT works closely with the DCRT, described below, and, with approval of the OC, may designate and utilize additional subcommittees or task groups as needed to accomplish specific tasks or responsibilities.

Data Collection and Reporting Team (DCRT)

The Data Collection and Reporting Team consists of the agency representatives and contractors responsible for data collection and reporting. The DCRT is responsible for coordinating monitoring activities, identifying and resolving any issues involving data collection and reporting, and making recommendations for revision of data collection and reporting procedures to the TPRT. The DCRT prepared the monitoring plan as well as the associated Quality Assurance Project Plan (QAPP) (Entrix, Inc., 1997). The DCRT met monthly during the first three years of operation, quarterly during the fourth year, and monthly during the final year.

Data Management

Each agency collecting data is responsible for its own internal data quality and management procedures. These are detailed in the QAPP. In addition, each agency submits its data to the San Francisco Estuary Institute (SFEI), which, through a cooperative agreement with USBR, compiles and reports project findings.

Reporting

The San Francisco Estuary Institute assembles, summarizes, and distributes monthly, quarterly and annual reports. Monthly and quarterly data reports consist of primary data from the 14 key monitoring stations as depicted in Table 3: SLD (A, B), Mud Slough (C, D, E, I), Salt Slough (F), wetland channels (J, K, L2, M2), and the San Joaquin River (G, H, N). The monthly report presents data collected during that particular month, including the calculated selenium load discharged at Station B, the terminus of the SLD. Quarterly data reports consist of all available data from all stations during a 3-month period. SFEI also prepares quarterly narrative and graphical summaries of the most recent Project data. The focus of SFEI is to report data and information from all sampling sites in a timely manner. All reports are distributed to the participating parties and are available to the public upon request.

A web site for the GBP provides current reports describing Project results. Also available are pre-Project information, related scientific studies, photographs of many of the stations, and other related topics. Visit the GBP web site by first connecting to USBR Mid-Pacific Region's home page at http://www.mp.usbr.gov/ and then select projects and then select Grassland Bypass Project.

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GRASSLAND BYPASS PROJECT

2

Drainage Control Activities by Grassland Area Farmers

Joseph C. McGahan,
Drainage Coordinator

Introduction

The Grassland Area Farmers formed a regional drainage entity in March 1996 under the umbrella of the San Luis and Delta-Mendota Water Authority to implement the Grassland Bypass Project. The Project consolidates subsurface drainage flows on a regional basis and utilizes a portion of the federal San Luis Drain to convey the flows around the habitat areas (see Figure 1). Participants include the Broadview Water District, Charleston Drainage District, Firebaugh Canal Water District, Pacheco Water District, Panoche Drainage District, Widren Water District and the Camp 13 Drainage District (located in part of Central California Irrigation District). This entity includes approximately 97,000 gross acres of irrigated farmland on the westside of the San Joaquin Valley, referred to as the Grassland Drainage Area. The area is highly productive, producing an estimated $113 Million annually in agricultural crop market value, with an additional estimated $126 Million generated for the local and regional economies, for a total estimated economic value of $239 Million.

The Grassland Area Farmers have implemented several activities aimed at reducing discharge of subsurface drainage waters to the San Joaquin River. These activities have included the Grassland Bypass Project and the San Joaquin River Water Quality Improvement Project. They also include: formation of a regional drainage entity, newsletters and other communication with the farmers, a monitoring program, using State Revolving Fund loans for improved irrigation systems, utilizing and installing drainage recycling systems to mix subsurface drainage water with irrigation supplies under strict limits, tiered water pricing and tradable loads programs.

Grassland Bypass Project

The Grassland Bypass Project is an innovative program that was designed to improve water quality in the channels used to deliver water to wetland areas. Prior to the Project, subsurface drainage water was conveyed through those channels in route to the San Joaquin River and limited their availability to deliver high-quality habitat supplies. The Project consolidates subsurface drainage flows on a regional basis and utilizes a portion of the federal San Luis Drain to convey the flows around the habitat areas. Figure 2 shows the discharge from the Grassland Bypass Project for the initial 5 years including Water Year (WY) 2001.

Negotiations between the San Luis & Delta-Mendota Water Authority and the U.S. Bureau of Reclamation to utilize a portion of the San Luis Drain for the Project commenced in 1988. Stakeholders included in the process were: U.S. Environmental Protection Agency, U.S. Fish & Wildlife Service, California Department of Fish and Game, the Central Valley Regional Water Quality Control Board, Environmental Defense, Contra Costa County and Contra Costa Water District. In late 1995, environmental documentation for the first five years was completed and the Use Agreement was signed. Discharge through the project began in September 1996. In September 2001, the Use Agreement was extended for another 8 years and 3 months (through December 2009). An Environmental Impact Report/Environmental Impact Statement was completed and on September 7, 2001 the Central Valley Regional Water Quality Control Board issued new Waste Discharge Requirements. Other items completed to support the continued use were a Biological Assessment/Biological Opinion, a selenium Total Maximum Monthly Load (TMML) report submitted by the Regional Board to EPA, and a continued monitoring program. The new Use Agreement contains continued reductions in selenium discharge until ultimately TMML limits are achieved in 2005 for above normal and wet years and continued progress is made to meet water quality objectives in 2010 for below normal, dry and critical years. The future load limits are shown on Figure 3.

The benefits of the Grassland Bypass Project are well documented. In WY 2001, drainage volume has been reduced 47%, selenium load has been reduced 56%, salt load has been reduced 28% and boron load has been reduced 41%, all from pre-project conditions in WY 1996. In WY 1996, prior to the Grassland Bypass Project, the mean selenium concentration in Salt Slough at Lander Avenue was 16 μS/cm. Since October 1996, the 2 μS/cm water quality objective for Salt Slough has been met in all months except one. The only month in which objectives were not met was February 1998 when uncontrollable flood flows were mixed with subsurface drainage water and could not be contained within the Grassland Bypass Project (that month the selenium concentration in Salt Slough was 4 μS/cm). In WY 1996 the mean selenium concentration at Camp 13 Ditch was 55.9 parts per billion (μS/cm). In WY 1997, the first year of operation of the Grassland Bypass Project, the mean selenium concentration at Camp 13 Ditch was 2.6 μS/cm. This value was slightly above the wetland selenium objective of 2 μS/cm. In April, 1998, specific actions

Figure 1. Grassland Drainage Area Location Map

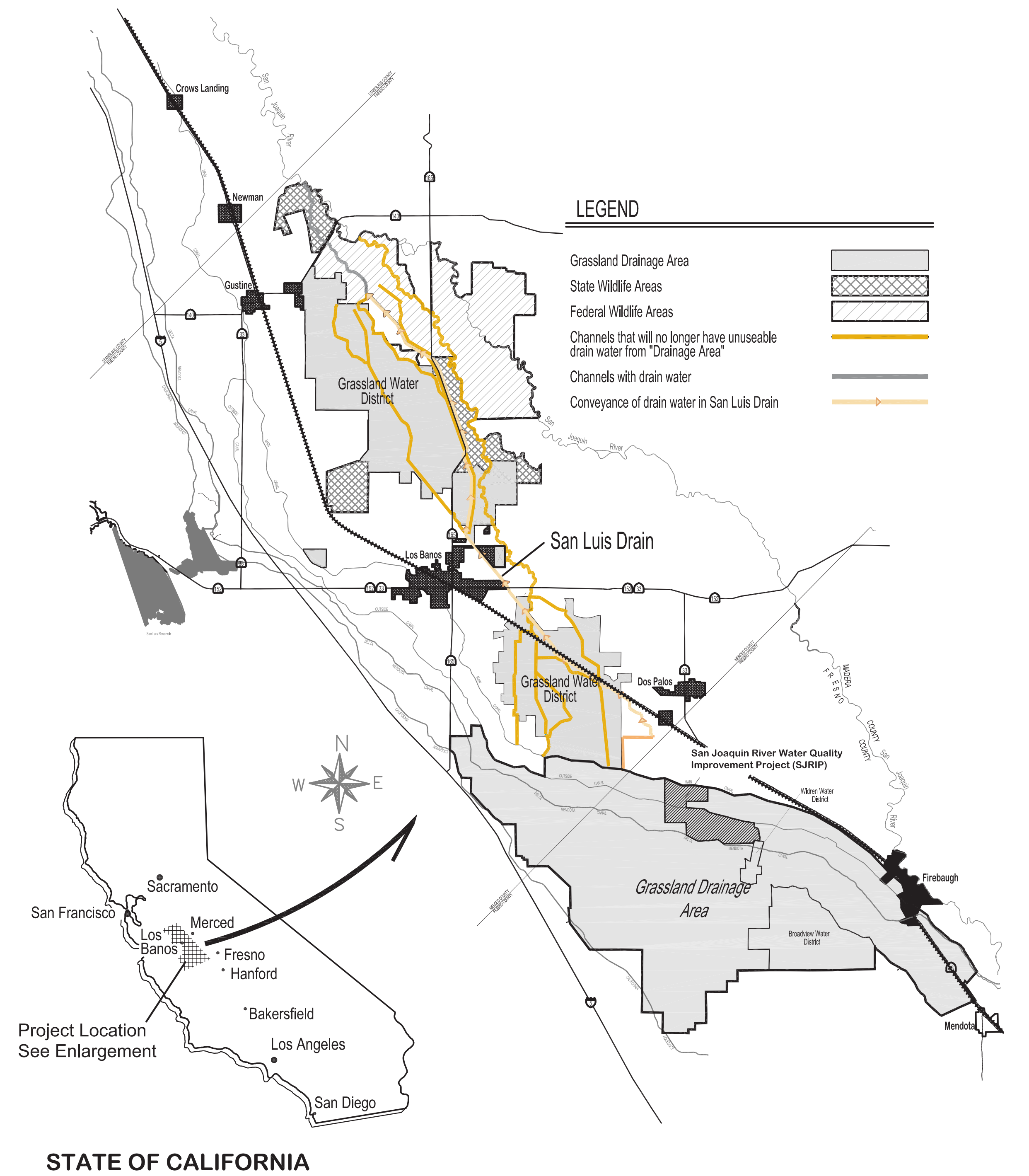


Figure 1
Grassland Drainage Area
Location Map

SUMMERS ENGINEERING, INC.
Consulting Engineers
HANFORD CALIFORNIA
DECEMBER 2001

Figure 2. Discharge from the Grassland Bypass Project October 1996 through September 2001

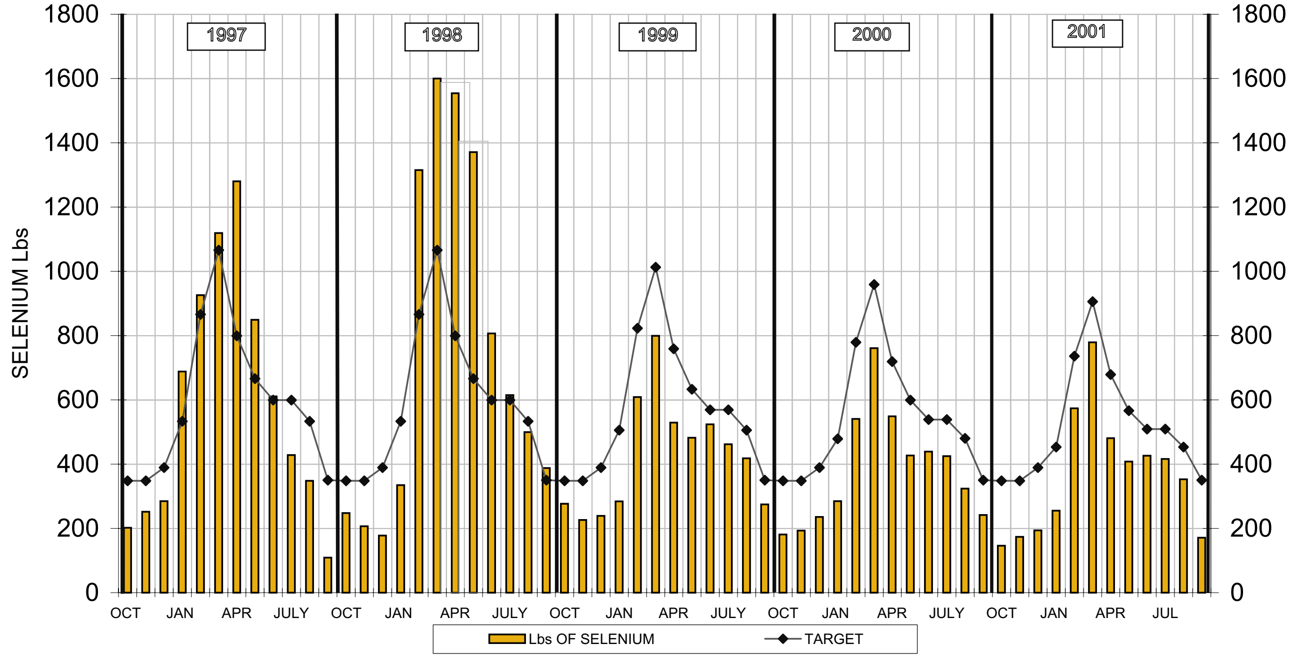


Figure 3. Grassland Drainage Area Selenium Discharge and Targets

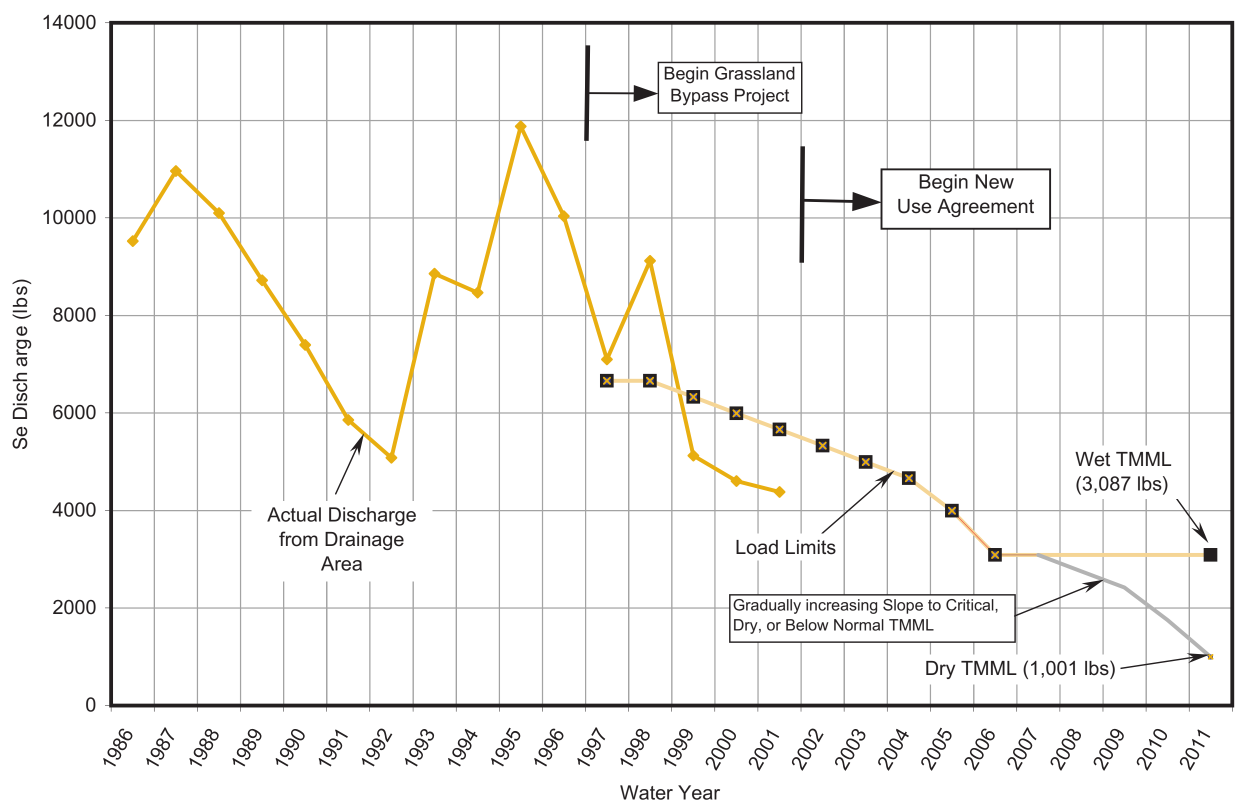


Figure 4

LEGEND

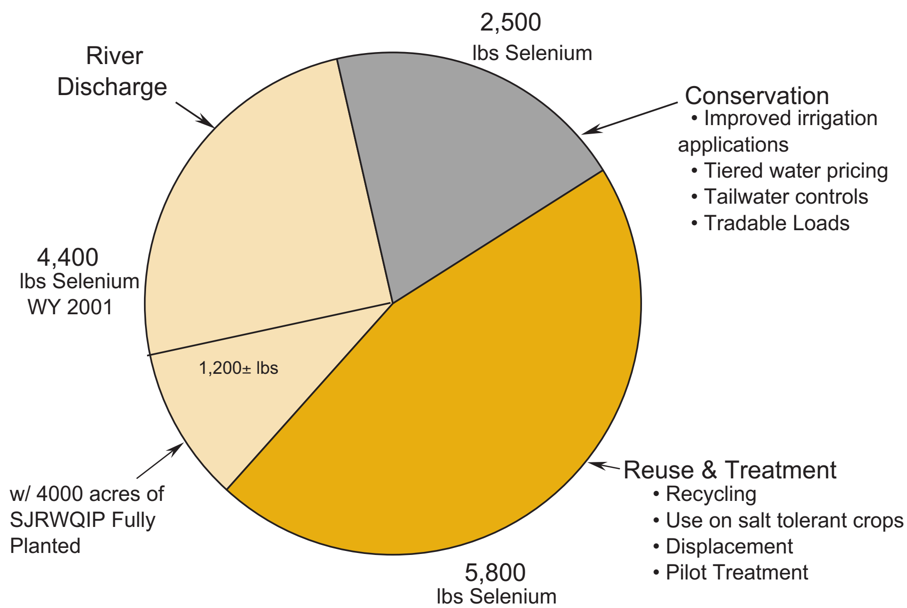
	Acreage	Crop
	20	Salado Alfalfa
	72	Alfalfa Seed
	122	Alfalfa / Pasture Grass
	220	Asparagus
	336	Alfalfa Seed / Pasture Grass
	572	Alfalfa
	180	Alfalfa - Firebaugh Canal Water District
	457	Pasture
	28	New Eucalyptus Trees
	1856	Fallow
		Fenced Areas (402 Acres)
	3863	Total Acres

PANOCHE DRAINAGE DISTRICT

San Joaquin River Water Quality
Improvement Project
2001 Crop Map

SUMMERS ENGINEERING, INC.
Consulting Engineers
HANFORD CALIFORNIA
April 2001

Figure 5. Historic Drainage Water (lbs selenium)
57,000 AF 12,700 lbs Se 240,000 Tons Salt



were taken to eliminate any possible subsurface drainage discharges from the Grassland Drainage Area into the Camp 13 Slough and other discharge points. Since that time there have been no discharges from the Grassland Drainage Area into wetland channels.

San Joaquin River Water Quality Improvement Project

Funds provided from Proposition 13 allowed for the purchase and improvement of 4,000 acres of land within the Grassland Drainage Area as part of the San Joaquin River Water Quality Improvement Project (SJRIP) for the purpose of drain water disposal. The first phase of the SJRIP was implemented in the winter of WY 2001 with the planting of salt tolerant crops and construction of distribution facilities. 1,821 acres were irrigated with drainage water or blended water. This resulted in a displacement of 1,025 pounds of selenium, 14,500 tons of salt and 62,000 pounds of boron, which were prevented from discharging to the Grassland Bypass Project and to the San Joaquin River. The location of the SJRIP Project is shown in Figure 1 and the cropping details for WY 2001 are shown in Figure 4. The SJRIP project is the key for the Grassland Drainage Area as a whole to meet future selenium load limits. This project will ultimately allow for planting and irrigation of the entire 4,000 acres with drainage water. Future phases call for acquisition of additional acreage, installation of subsurface drainage systems and implementation of treatment and salt disposal components.

A component of this future phase is being implemented with Proposition 13 funds. Subsurface drains are being installed in 550 acres within the SJRIP area. Irrigation systems are being improved to distribute drainage water to the land and crops are being planted to utilize the subsurface drainage water. This project is called the Grassland Integrated Drainage Management Project.

Other Activities

The Grassland Area Farmers and member districts are continuing advances into drainage management and disposal with the cooperation of federal and state agencies. Research is being undertaken in algal bacteria selenium treatment, reverse osmosis treatment, flow through selenium removal and individual district reuse projects. Continued funding is being sought for these activities. An estimate has been made of the components of subsurface drainage within the GDA. This information is shown in Figure 5.

Future regulations may include salt and boron discharge limits to the San Joaquin River. The Grassland Area Farmers are active participants in this process as well other regulatory efforts such as the dissolved oxygen issue in the San Joaquin River.

G R A S S L A N D B Y P A S S P R O J E C T

3 Flow and Salinity Monitoring

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Summary

Flow and salinity measurements were taken to monitor the effects of the Grassland Bypass Project (GBP) on the San Luis Drain (SLD), Mud Slough, Salt Slough, and the San Joaquin River. The U.S. Geological Survey (USGS) operated four monitoring stations and the San Luis & Delta-Mendota Water Authority (SLDMWA) operated one station. The California Regional Water Quality Control Board, Central Valley Region (CVRWQCB), measured the salinity of water quality samples collected at these five sites and six other sites where flow is not measured. The San Francisco Estuary Institute (SFEI) compiled this information in monthly and quarterly reports.

Table 1 is a summary of flow and EC sampling methods at the six stations.

Tables 2 - 7 summarize monthly flow, salinity, and salt loads at six locations during the five years of the Project. Note that the historical salinity and load values have been updated and differ from the Water Year 1999 report and errata sheets.

The data record for Water Year 2001 has been compiled for all stations. Flow and salinity sensors performed properly at all stations with a few problems. Data were lost at Stations D and F due to vandalism and equipment failures.

Figure 1 shows the pattern of rainfall and discharge from the 97,000 acre Grassland Drainage Area (GDA) during Water Year 2001. Rain fell during October, November, January, February, March, and April. Peak flow for Water Year 2001 was 82 cubic feet per second (cfs), well below the capacity of the SLD. No drain water was discharged from the Project into wetland water supply channels during Water Year 2001.

The GBP conveyed approximately 28,200 acre-feet of drainage water and about 120,000 tons of salt from the GDA in the San Luis Drain during Water Year 2001. This was about 10 percent less than the volume and load discharged in the previous water year.

Flow and Salinity Measurements

The flow of water passing a point is expressed in terms of volume and time – cubic feet per second or acre-feet per day/month/year. There are various methods for measuring flow.

The salinity of water is estimated by measuring electrical conductivity (EC), which is the ability of a solution to pass an electric current. Current is carried by inorganic solids such as chloride, nitrate, sulfate, and phosphate ions dissolved in the solution, as well as

Table 1. Flow & Salinity Monitoring Methods

Station	Agency	Parameter	Sample frequency	EC to TDS Factor (b)
A	SLDMWA	Flow	Continuous	
	SLDMWA	EC	Continuous	0.74
B	USGS	Flow	Continuous	
	USGS	EC	Continuous	0.74
	CVRWQCB	EC	Daily composite of six samples	
C		Flow	Derived (a)	
	CVRWQCB	EC	Weekly grab	0.68
D	USGS	Flow	Continuous	
	USGS	EC	Continuous	0.69
F	USGS	Flow	Continuous	
	USGS	EC	Continuous	0.68
N	USGS	Flow	Continuous	
	USGS	EC	Continuous	0.62
	CVRWQCB	EC	Daily composite of six samples	

(a) Flow passing Station C is calculated as difference between flows at Stations D and B.
(b) CVRWCB, 1998. Page 15; San Luis Drain factor revised 10/2000.

cations like sodium calcium, magnesium, iron, and aluminum. Total dissolved solids (TDS) is a lab procedure that measures the mass of solids in a solution. The CVRWQCB has calculated factors to convert EC to TDS.

The method for determining flow-weighted concentrations and calculating loads of salt are explained in CVRWQCB, 1998 (pp. 4 - 8).

Station A

Location	San Luis Drain Check 17, near South Dos Palos, California (USGS 11262890) (CVRWQCB MER562)
Responsibility	San Luis & Delta-Mendota Water Authority (Summers Engineering)
Parameters	Stage, electrical conductivity, temperature
Equipment	Sharp-crested weir, stilling well with a Stevens recorder and shaft encoder, staff gauge, weir stick; electrical conductivity/ temperature sensor; data logger, telephone and modem; Sigma autosampler.

Description

Station A is located near South Dos Palos, California. Its purpose is to measure the volume and quality of drainwater as it enters the San Luis Drain from the GDA.

Data Summary

Table 2 and Figure 2 summarize the flow and salinity of water that passed Station A during the five years of the Project.

During Water Year 2001, the total volume of drainage water that passed this site was 27,005 acre-feet. The average flow that passed Station A was 37.4 cfs. The flow reached a maximum of 83 cfs on March 7, 2001. The flow-weighted EC of water that passed the site was about 4,634 microSiemens per centimeter (µS/cm), with a brief peak on March 15, 2001 of 5,810 µS/cm. The load of salt discharged from the GDA was about 125,400 tons during Water Year 2001.

The total volume of water discharged during Water Year 2001 was about 8 percent less than that discharged during Water Year 2000. However, the load of salt discharged was about 3 percent less than Water Year 2000.

Figure 1. Daily Rainfall and Discharge from the Grassland Bypass Project

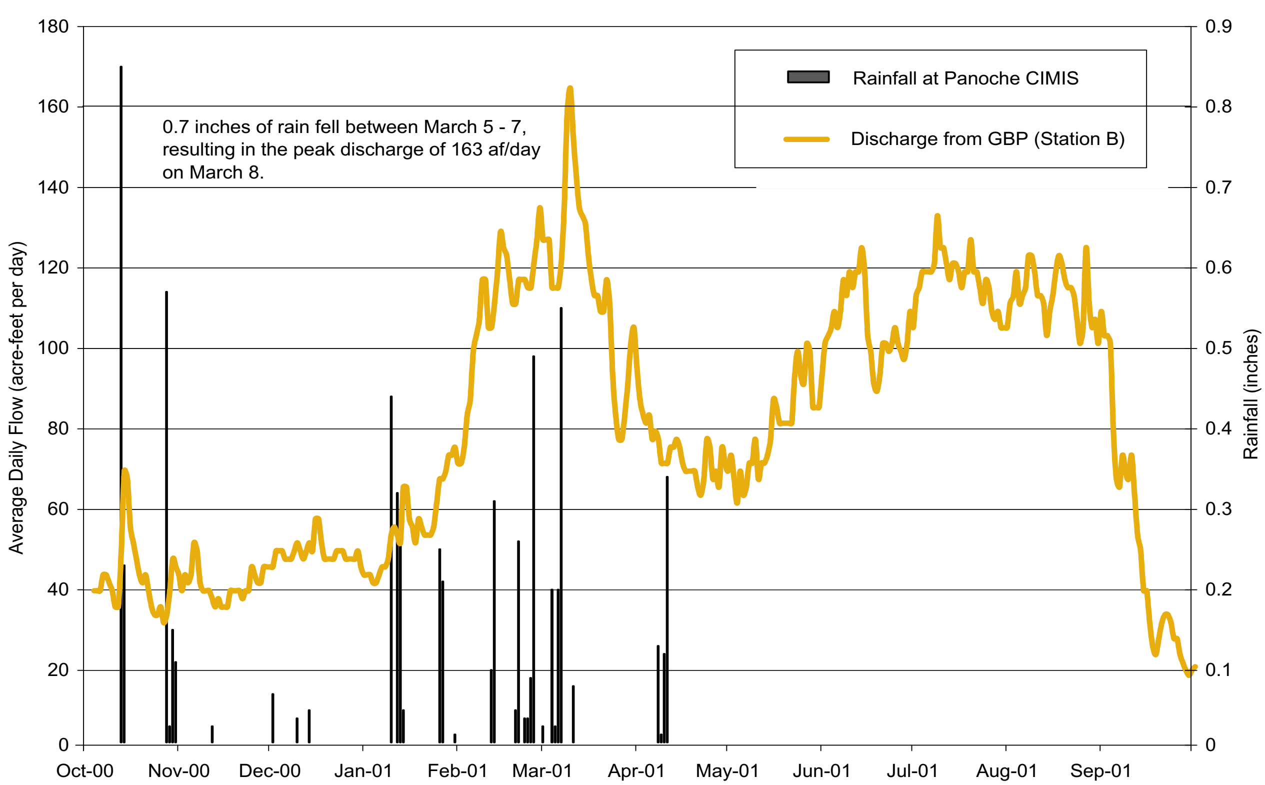


Table 2. Monthly Flow and Salinity of Water Entering the San Luis Drain (Station A) WY 1997 - 2001

	Flow				Salinity					
	Monthly Average		Total		FW EC		TDS		Salt load	
	cfs		acre-feet		µS/cm		mg/L		tons	
Oct-1996	22.0	L	1,350	L	4,326	Rr	3,201	Rr	5,877	Rr
Nov-1996	24.2	L	1,437	L	3,812	Rr	2,821	Rr	5,513	Rr
Dec-1996	29.6	L	1,818	L	4,775	Rr	3,534	Rr	8,737	Rr
Jan-1997	62.2	L	3,827	L	4,804	Rr	3,555	Rr	18,503	Rr
Feb-1997	78.4	L	4,356	L	5,256	Rr	3,889	Rr	23,042	Rr
Mar-1997	83.5	L	5,131	L	4,628	Rr	3,425	Rr	23,898	Rr
Apr-1997	77.6	L	4,619	L	5,391	Rr	3,989	Rr	25,060	Rr
May-1997	69.9	L	4,301	L	4,654	Rr	3,444	Rr	20,145	Rr
Jun-1997	54.6	L	3,251	L	4,823	Rr	3,569	Rr	15,780	Rr
Jul-1997	53.0	L	3,257	L	4,217	Rr	3,121	Rr	13,823	Rr
Aug-1997	49.7	L	3,055	L	3,722	Rr	2,754	Rr	11,443	Rr
Sep-1997	23.3	L	1,384	L	3,311	Rr	2,450	Rr	4,612	Rr
Oct-1997	21.7	L	1,335	L	5,065	Rr	3,748	Rr	6,805	Rr
Nov-1997	16.7	L	994	L	4,640	Rr	3,434	Rr	4,642	Rr
Dec-1997	17.4	L	1,070	L	5,016	Rr	3,712	Rr	5,401	Rr
Jan-1998	20.0	L	1,230	L	5,393	Rr	3,991	Rr	6,676	Rr
Feb-1998	123.0	L	6,833	L	3,200	Rr	2,368	Rr	22,006	Rr
Mar-1998	115.1	L	7,075	L	4,599	Rr	3,403	Rr	32,746	Rr
Apr-1998	91.5	L	5,444	L	4,914	Rr	3,636	Rr	26,923	Rr
May-1998	76.7	L	4,714	L	4,952	Rr	3,664	Rr	23,493	Rr
Jun-1998	61.0	L	3,629	L	5,109	Rr	3,781	Rr	18,659	Rr
Jul-1998	73.8	L	4,538	L	4,408	Rr	3,262	Rr	20,132	Rr
Aug-1998	62.6	L	3,849	L	4,267	Rr	3,158	Rr	16,529	Rr
Sep-1998	47.7	L	2,839	L	3,938	Rr	2,914	Rr	11,252	Rr
Oct-1998	27.6	G	1,700	G	4,972	Gr	3,679	Gr	8,506	Gr
Nov-1998	20.4	G	1,210	G	5,371	Gr	3,975	Gr	6,541	Gr
Dec-1998	18.6	G	1,140	G	5,268	Gr	3,898	Gr	6,044	Gr
Jan-1999	22.7	G	1,390	G	5,010	Gr	3,707	Gr	7,008	Gr
Feb-1999	54.8	G	3,040	G	4,687	Gr	3,468	Gr	14,340	Gr
Mar-1999	52.3	G	3,220	G	5,363	Gr	3,969	Gr	17,379	Gr
Apr-1999	35.9	G	2,140	G	5,511	Gr	4,078	Gr	11,869	Gr
May-1999	48.7	G	3,000	G	4,973	Gr	3,680	Gr	15,014	Gr
Jun-1999	60.9	G	3,620	G	4,581	Gr	3,390	Gr	16,689	Gr
Jul-1999	64.8	G	3,990	G	4,230	Gr	3,130	Gr	16,986	Gr
Aug-1999	64.1	G	3,940	G	3,648	Gr	2,700	Gr	14,465	Gr
Sep-1999	34.9	G	2,080	G	4,234	Gr	3,133	Gr	8,863	Gr
Oct-1999	18.9	S	1,162	Sr	5,423	Rr	4,013	Rr	6,341	Rr
Nov-1999	21.4	S	1,273	Sr	4,693	Rr	3,473	Rr	6,010	Rr
Dec-1999	16.5	S	1,015	Sr	4,853	Rr	3,591	Rr	4,957	Rr
Jan-2000	20.8	S	1,281	Sr	4,158	Rr	3,077	Rr	5,359	Rr
Feb-2000	53.4	S	3,074	Sr	4,554	Sr	3,370	Sr	14,089	Sr
Mar-2000	52.3	S	3,217	Sr	5,051	Sr	3,738	Sr	16,353	Sr
Apr-2000	43.9	S	2,614	Sr	4,669	Sr	3,455	Sr	12,283	Sr
May-2000	47.3	S	2,906	Sr	4,150	Sr	3,071	Sr	12,137	Sr
Jun-2000	63.6	S	3,783	Sr	4,269	Sr	3,159	Sr	16,253	Sr
Jul-2000	61.9	S	3,804	Sr	4,017	Sr	2,973	Sr	15,378	Sr
Aug-2000	58.3	S	3,586	Sr	3,669	Sr	2,715	Sr	13,241	Sr
Sep-2000	27.5	S	1,637	Sr	4,230	Sr	3,130	Sr	6,967	Sr
Oct-2000	15.8	S	972	Sr	4,340	S	3,212	S	4,245	Sr
Nov-2000	15.8	S	940	Sr	4,733	S	3,502	S	4,477	Sr
Dec-2000	18.3	S	1,126	Sr	4,713	S	3,488	S	5,341	Sr
Jan-2001	24.0	S	1,475	Sr	4,692	S	3,472	S	6,965	Sr
Feb-2001	56.6	S	3,142	Sr	4,635	S	3,430	S	14,656	Sr
Mar-2001	56.1	S	3,451	Sr	5,438	S	4,024	S	18,887	Sr
Apr-2001	36.7	S	2,184	Sr	5,183	S	3,835	S	11,392	Sr
May-2001	42.5	S	2,611	Sr	4,318	S	3,195	S	11,346	Sr
Jun-2001	51.7	S	3,077	Sr	4,340	S	3,212	S	13,440	Sr
Jul-2001	58.0	S	3,567	Sr	4,314	S	3,192	S	15,487	Sr
Aug-2001	54.8	S	3,372	Sr	4,096	S	3,031	S	13,900	Sr
Sep-2001	18.3	S	1,088	Sr	4,801	S	3,553	S	5,257	Sr

	Monthly Average mean cfs	Total total acre-feet	FW EC mean µS/cm	TDS mean mg/L	Salt load total tons
WY 1997	52.3	37,786	4,477	3,313	176,433
WY 1998	60.6	43,550	4,625	3,423	195,263
WY 1999	42.1	30,470	4,821	3,567	143,705
WY 2000	40.5	29,350	4,478	3,314	129,368
WY 2001	37.4	27,005	4,634	3,429	125,394

Performance

All equipment performed as required at this site and there were no gaps in data due to malfunction.

Station B

Location	San Luis Drain, near Gustine, California (USGS 11262895, CVRWQCB MER535)
Responsibility	US Geological Survey (flow, EC, temp), CVRWQCB (EC, water quality)
Parameters	Stage, velocity, electrical conductivity, temperature
Equipment	Nitrogen bubbler pressure sensor, 2 - acoustic velocity meters, monthly current meter readings, 2 - EC/temperature sensors, data logger, telephone and modem.

Description

Station B is located about 28 miles northwest of Station A, about 2 miles from the terminus of the Drain. It is the primary site for measuring the flow and selenium load discharged from the GDA into Mud Slough. The performance of the GBP to manage flows and selenium loads is assessed at this site.

Data Summary

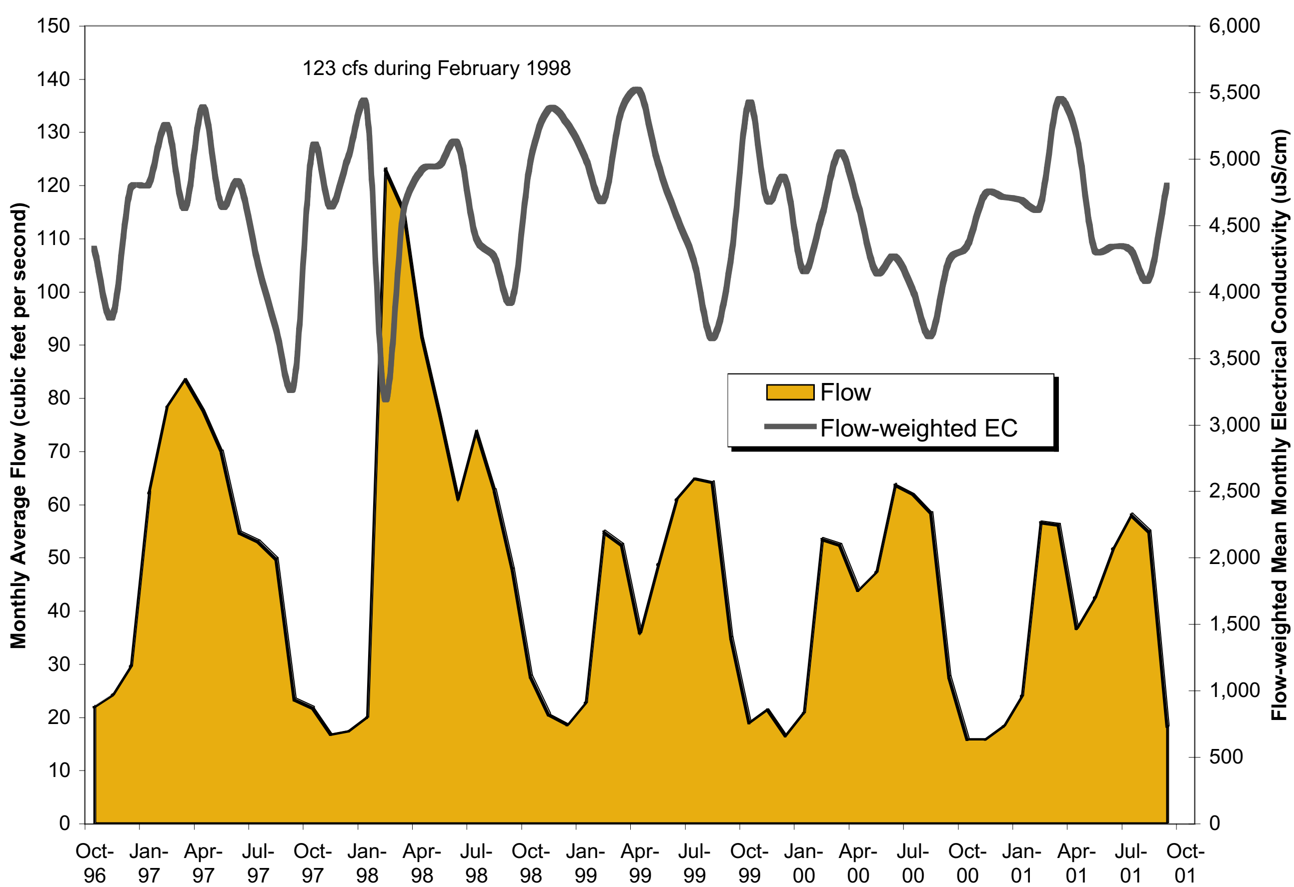
Table 3 and Figure 3 summarize the flow and salinity of water that passed Station B during the five years of the Project.

During Water Year 2001, the average flow that passed Station B was 39 cfs. The peak flow of 82 cfs occurred on March 8, 2001, one day after a similar peak at Station A. The total volume of drainage water that passed this site was 28,234 acre-feet.

EC ranged from 3,090 to 5,610 µS/cm, with a flow-weighted average of 4,166 µS/cm. About 120,000 tons of salt were discharged from the San Luis Drain into Mud Slough.

The total volume of water discharged during Water Year 2001 was about nine percent less than that discharged during the 2000 Water Year. The load of salt discharged was about 11 percent less than Water Year 2000.

Figure 2. Flow & Salinity of Water Entering the San Luis Drain (Station A)



Performance

EC and temperature data were collected every day except for three days during this water year. This was due to regular inspections and rinsing with vinegar to prevent algae accumulations on the sensor that have occurred in previous years.

Station C

Location Mud Slough, approximately 1/2 mile upstream of San Luis Drain terminus (CVRWQCB MER536)

Responsibility	CVRWQCB
Parameters	Electrical conductivity, temperature, pH, boron
Equipment	None. Weekly grab samples are taken here

Description

Station C is located in Mud Slough upstream from the end of the San Luis Drain. Water at this point comes from wetlands in the Grassland Water District. Data collected at this site are considered a baseline for measuring the impact of the GBP on the slough. The CVRWQCB collected weekly water quality samples here, and the US Fish & Wildlife Service sampled fish and invertebrates four times at this site.

Data Summary

Table 4 and Figure 4 summarize the flow and salinity of water that passed Station C during the five years of the Project. Flow was not measured at this site, but was estimated as the difference between flows passing Stations D and B.

During Water Year 2001, about 64,600 acre-feet of water passed this site at an average rate of 90 cfs. Flows peaked in mid-March at 385 cfs and diminished in August to less than 10 cfs. The salinity of water at this site was measured by the CVRWQCB in its weekly grab samples. The flow-weighted average EC of water at this site was 1,696 µS/cm. The water was most saline on April 26, 2001 at 3,460 µS/cm, and was about 700µS/cm during September 2000. About 92,700 tons of salt in water passed this site during Water Year 2001.

Figure 3. Flow & Salinity of Water in the San Luis Drain (Station B)

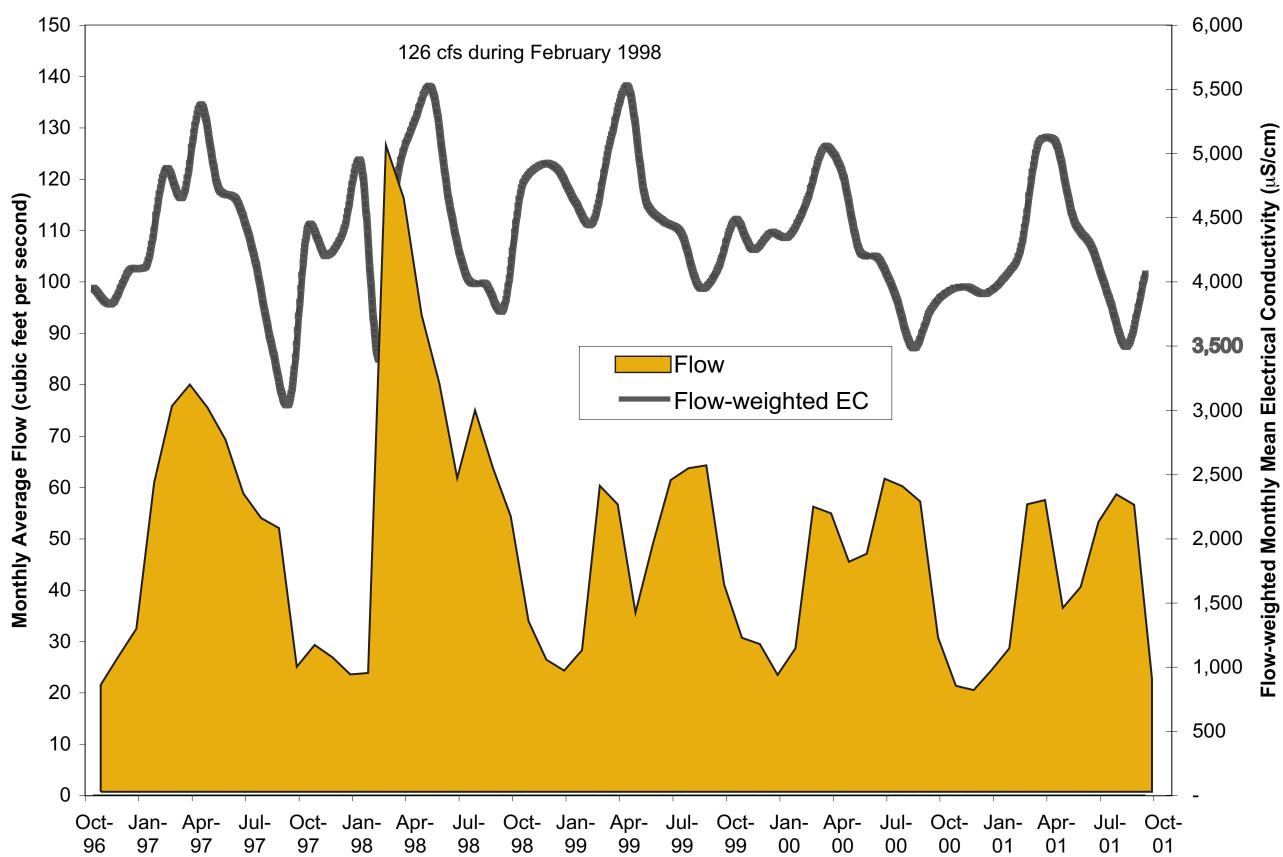


Table 3. Monthly Flow and Salinity of Water in the San Luis Drain (Station B) WY 1997 - 2001

	Flow				Salinity					
	Monthly Average cfs		Total acre-feet		FW EC µS/cm		TDS mg/L		Salt load tons	
Oct-1996	20.8	L	1,276	L	3,948	L	2,922	Lr	5,070	Lr
Nov-1996	26.4	L	1,569	L	3,830	L	2,834	Lr	6,048	Lr
Dec-1996	31.7	L	1,946	L	4,095	L	3,030	Lr	8,020	Lr
Jan-1997	60.2	L	3,703	L	4,142	L	3,065	Lr	15,433	Lr
Feb-1997	75.1	L	4,173	L	4,872	L	3,605	Lr	20,463	Lr
Mar-1997	79.3	L	4,876	L	4,669	L	3,455	Lr	22,913	Lr
Apr-1997	74.8	L	4,453	L	5,380	L	3,981	Lr	24,111	Lr
May-1997	68.6	L	4,215	L	4,730	L	3,500	Lr	20,063	Lr
Jun-1997	58.1	L	3,457	L	4,642	L	3,435	Lr	16,153	Lr
Jul-1997	53.3	L	3,277	L	4,206	L	3,112	Lr	13,873	Lr
Aug-1997	51.4	L	3,159	L	3,497	L	2,588	Lr	11,117	Lr
Sep-1997	24.3	L	1,445	L	3,077	L	2,277	Lr	4,474	Lr
Oct-1997	28.6	L	1,756	L	4,425	L	3,275	Lr	7,819	Lr
Nov-1997	26.2	L	1,558	L	4,206	L	3,112	Lr	6,594	Lr
Dec-1997	22.9	L	1,406	L	4,398	L	3,255	Lr	6,221	Lr
Jan-1998	23.1	L	1,421	L	4,919	L	3,640	Lr	7,036	Lr
Feb-1998	125.9	L	6,993	L	3,397	L	2,514	Lr	23,906	Lr
Mar-1998	115.6	L	7,106	L	4,788	L	3,543	Lr	34,244	Lr
Apr-1998	92.9	L	5,527	L	5,258	L	3,891	Lr	29,250	Lr
May-1998	79.5	L	4,890	L	5,494	L	4,066	Lr	27,036	Lr
Jun-1998	61.1	L	3,635	L	4,576	L	3,386	Lr	16,740	Lr
Jul-1998	74.3	L	4,572	L	4,020	L	2,975	Lr	18,494	Lr
Aug-1998	63.1	L	3,883	L	3,983	L	2,947	Lr	15,561	Lr
Sep-1998	53.7	L	3,193	L	3,798	L	2,811	Lr	12,203	Lr
Oct-1998	33.2	G	2,040	G	4,738	Gr	3,506	Gr	9,742	Gr
Nov-1998	25.7	G	1,530	G	4,909	Gr	3,633	Gr	7,546	Gr
Dec-1998	23.6	G	1,450	G	4,881	Gr	3,612	Gr	7,142	Gr
Jan-1999	27.6	G	1,700	G	4,628	Gr	3,425	Gr	7,909	Gr
Feb-1999	59.6	G	3,310	G	4,467	Gr	3,306	Gr	14,883	Gr
Mar-1999	56.0	G	3,450	G	5,117	Gr	3,787	Gr	17,743	Gr
Apr-1999	34.9	G	2,080	G	5,512	Gr	4,079	Gr	11,532	Gr
May-1999	48.2	G	2,960	G	4,637	Gr	3,431	Gr	13,830	Gr
Jun-1999	60.7	G	3,610	G	4,471	Gr	3,309	Gr	16,252	Gr
Jul-1999	63.0	G	3,870	G	4,380	Gr	3,241	Gr	17,068	Gr
Aug-1999	63.6	G	3,910	G	3,960	Gr	2,930	Gr	15,596	Gr
Sep-1999	40.3	G	2,400	G	4,094	Gr	3,030	Gr	9,890	Gr
Oct-1999	30.0	G	1,847	G	4,482	Gr	3,317	Gr	8,329	Gr
Nov-1999	28.8	G	1,714	G	4,253	Gr	3,147	Gr	7,334	Gr
Dec-1999	22.8	G	1,400	G	4,383	Gr	3,243	Gr	6,177	Gr
Jan-2000	27.9	G	1,716	G	4,355	Gr	3,223	Gr	7,520	Gr
Feb-2000	55.5	G	3,191	G	4,622	Gr	3,420	Gr	14,844	Gr
Mar-2000	54.2	G	3,330	G	5,047	Gr	3,735	Gr	16,916	Gr
Apr-2000	44.8	G	2,660	G	4,863	Gr	3,599	Gr	13,037	Gr
May-2000	46.4	G	2,850	G	4,238	Gr	3,136	Gr	12,157	Gr
Jun-2000	61.0	G	3,630	G	4,190	Gr	3,101	Gr	15,313	Gr
Jul-2000	59.5	G	3,660	G	3,899	Gr	2,885	Gr	14,344	Gr
Aug-2000	56.5	G	3,470	G	3,485	Gr	2,579	Gr	12,180	Gr
Sep-2000	30.1	G	1,790	G	3,792	Gr	2,806	Gr	6,843	Gr
Oct-2000	20.6	G	1,270	G	3,930	G	2,908	Gr	4,991	Gr
Nov-2000	19.8	G	1,180	G	3,960	G	2,930	Gr	4,690	Gr
Dec-2000	23.7	G	1,460	G	3,910	G	2,893	Gr	5,733	Gr
Jan-2001	27.9	G	1,720	G	4,020	G	2,975	Gr	6,946	Gr
Feb-2001	56.0	G	3,110	G	4,245	Gr	3,141	Gr	13,279	Gr
Mar-2001	56.8	G	3,490	G	5,080	G	3,759	Gr	17,747	Gr
Apr-2001	35.8	G	2,130	G	5,090	G	3,767	Gr	10,926	Gr
May-2001	39.9	G	2,454	G	4,488	Gr	3,321	Gr	11,082	Gr
Jun-2001	52.6	G	3,130	G	4,276	Gr	3,164	Gr	13,461	Gr
Jul-2001	57.9	G	3,560	G	3,870	G	2,864	Gr	13,833	Gr
Aug-2001	55.9	G	3,440	G	3,500	G	2,590	Gr	12,074	Gr
Sep-2001	22.0	G	1,310	G	4,060	G	3,004	Gr	5,246	Gr

	Monthly Average mean cfs	Total total acre-feet	FW EC mean µS/cm	TDS mean mg/L	Salt load total tons
WY 1997	52.0	37,550	4,257	3,150	167,739
WY 1998	63.9	45,939	4,439	3,284	205,104
WY 1999	44.7	32,310	4,650	3,441	149,133
WY 2000	43.1	31,258	4,301	3,183	134,994
WY 2001	39.1	28,254	4,202	3,110	120,008

Station D

Location	Mud Slough near Gustine, California (USGS 11262900) (CVRWQCB MER542)
Responsibility	US Geological Survey (flow, EC, temp), CVRWQCB (EC, water quality)
Parameters	Stage, electrical conductivity, temperature
Equipment	Nitrogen bubbler pressure transducer, electrical conductivity/temperature sensor, data logger, cellular telephone and modem.

Description

Station D is located in Mud Slough downstream from the terminus of the SLD.

Data summary

Table 5 and Figure 5 summarize the daily flow and salinity of water that passed Station D during the five years of the Project.

During Water Year 2001, approximately 92,900 acre-feet of water passed this site. The GBP contributed 30% of this flow. The average flow passing Station D was 129 cfs. The flow-weighted average EC of water passing this site was 2,769 µS/cm. Approximately 214,400 tons of salt flowed past this site, 44 percent coming from the GBP.

Performance

EC and temperature data were lost for 61 days during November, December, February, April, May, and September due to vandalism and equipment failure. The EC/temperature probe was replaced three times. The data logger failed in April and again in May 2001.

Station F

Location	Salt Slough at Highway 165 near Stevinson, California (USGS 11261100) (CVRWQCB MER531)
Responsibility	US Geological Survey
Parameters	Stage, electrical conductivity, temperature
Equipment	Nitrogen bubbler pressure transducer, electrical conductivity/temperature sensor, data logger, cellular telephone and modem.

Description

Station F is where flow and water quality are monitored in Salt Slough. The GBP has removed the GDA's agricultural drainage water from this stream. The water in this channel is derived from wetlands and farmlands outside the GDA area.

Figure 4. Flow & Salinity of Water in Mud Slough Upstream of Drainage Discharge (Station C)

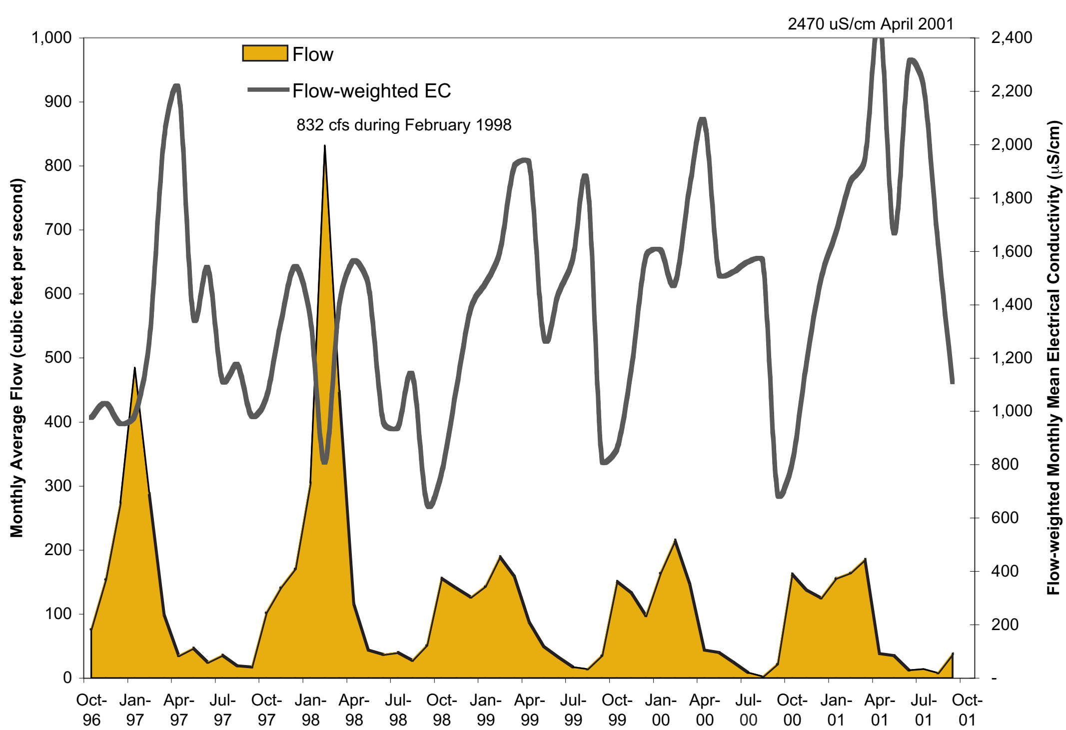


Table 4. Monthly Flow and Salinity of Water in Mud Slough Upstream of Drainage Discharge (Station C) WY 1997 - 2001

	Flow (*)				Salinity					
	Monthly Average cfs		Total acre-feet		FW EC µS/cm		TDS mg/L		Salt load tons	
Oct-1996	76.4	Gr	4,704	Gr	975	Rr	663	Rr	4,242	Rr
Nov-1996	154.6	Gr	9,181	Gr	1,030	Rr	700	Rr	8,745	Rr
Dec-1996	273.3	Gr	16,804	Gr	954	Rr	649	Rr	14,825	Rr
Jan-1997	484.8	Gr	29,807	Gr	984	Rr	669	Rr	27,124	Rr
Feb-1997	287.9	Gr	16,007	Gr	1,259	Rr	856	Rr	18,637	Rr
Mar-1997	98.7	Gr	6,044	Gr	2,026	Rr	1,378	Rr	11,324	Rr
Apr-1997	35.2	Gr	2,097	Gr	2,205	Rr	1,499	Rr	4,276	Rr
May-1997	46.4	Gr	2,875	Gr	1,357	Rr	923	Rr	3,608	Rr
Jun-1997	24.4	Gr	1,453	Gr	1,537	Rr	1,045	Rr	2,065	Rr
Jul-1997	35.7	Gr	2,193	Gr	1,116	Rr	759	Rr	2,263	Rr
Aug-1997	19.1	Gr	1,181	Gr	1,176	Rr	800	Rr	1,284	Rr
Sep-1997	17.3	Gr	1,035	Gr	981	Rr	667	Rr	939	Rr
Oct-1997	102.4	Gr	6,304	Gr	1,049	Rr	713	Rr	6,116	Rr
Nov-1997	141.8	Gr	8,422	Gr	1,330	Rr	904	Rr	10,359	Rr
Dec-1997	171.1	Gr	10,554	Gr	1,543	Rr	1,049	Rr	15,060	Rr
Jan-1998	304.9	Gr	18,749	Gr	1,352	Rr	919	Rr	23,442	Rr
Feb-1998	832.1	Gr	46,197	Gr	808	Rr	549	Rr	34,520	Rr
Mar-1998	447.4	Gr	27,484	Gr	1,400	Rr	952	Rr	35,584	Rr
Apr-1998	116.1	Gr	6,923	Gr	1,566	Rr	1,065	Rr	10,026	Rr
May-1998	43.5	Gr	2,660	Gr	1,474	Rr	1,002	Rr	3,626	Rr
Jun-1998	36.6	Gr	2,175	Gr	961	Rr	653	Rr	1,933	Rr
Jul-1998	39.7	Gr	2,408	Gr	937	Rr	637	Rr	2,087	Rr
Aug-1998	27.7	Gr	1,697	Gr	1,138	Rr	774	Rr	1,786	Rr
Sep-1998	51.3	Gr	3,067	Gr	657	Rr	447	Rr	1,863	Rr
Oct-1998	155.8	Gr	9,570	Gr	764	Rr	520	Rr	6,762	Rr
Nov-1998	140.3	Gr	8,370	Gr	1,081	Rr	735	Rr	8,368	Rr
Dec-1998	126.4	Gr	7,780	Gr	1,385	Rr	942	Rr	9,965	Rr
Jan-1999	143.4	Gr	8,820	Gr	1,479	Rr	1,006	Rr	12,064	Rr
Feb-1999	189.4	Gr	10,540	Gr	1,598	Rr	1,087	Rr	15,576	Rr
Mar-1999	159.0	Gr	9,780	Gr	1,919	Rr	1,305	Rr	17,356	Rr
Apr-1999	87.1	Gr	5,160	Gr	1,929	Rr	1,312	Rr	9,205	Rr
May-1999	49.3	Gr	3,030	Gr	1,280	Rr	870	Rr	3,587	Rr
Jun-1999	32.8	Gr	1,960	Gr	1,441	Rr	980	Rr	2,612	Rr
Jul-1999	17.2	Gr	1,060	Gr	1,572	Rr	1,069	Rr	1,541	Rr
Aug-1999	14.3	Gr	880	Gr	1,855	Rr	1,261	Rr	1,510	Rr
Sep-1999	35.4	Gr	2,100	Gr	817	Rr	556	Rr	1,587	Rr
Oct-1999	151.0	Gr	9,283	Gr	857	Rr	583	Rr	7,357	Rr
Nov-1999	133.2	Gr	7,916	Gr	1,156	Rr	786	Rr	8,463	Rr
Dec-1999	97.2	Gr	5,960	Gr	1,580	Rr	1,074	Rr	8,709	Rr
Jan-2000	164.1	Gr	10,064	Gr	1,606	Rr	1,092	Rr	14,947	Rr
Feb-2000	215.5	Gr	12,419	Gr	1,478	Rr	1,005	Rr	16,975	Rr
Mar-2000	146.8	Gr	9,030	Gr	1,845	Rr	1,255	Rr	15,407	Rr
Apr-2000	43.4	Gr	2,590	Gr	2,087	Rr	1,419	Rr	4,999	Rr
May-2000	40.1	Gr	2,470	Gr	1,516	Rr	1,031	Rr	3,463	Rr
Jun-2000	24.4	Gr	1,450	Gr	1,523	Rr	1,036	Rr	2,042	Rr
Jul-2000	8.8	Gr	540	Gr	1,560	Rr	1,061	Rr	779	Rr
Aug-2000	2.4	Gr	150	Gr	1,563	Rr	1,063	Rr	217	Rr
Sep-2000	22.0	Gr	1,310	Gr	694	Rr	472	Rr	841	Rr
Oct-2000	162.4	Gr	9,964	Gr	801	Rr	545	Rr	7,381	Rr
Nov-2000	137.4	Gr	8,176	Gr	1,179	Rr	802	Rr	8,915	Rr
Dec-2000	125.3	Gr	7,702	Gr	1,494	Rr	1,016	Rr	10,641	Rr
Jan-2001	156.0	Gr	9,590	Gr	1,669	Rr	1,135	Rr	14,802	Rr
Feb-2001	164.2	Gr	9,120	Gr	1,860	Rr	1,265	Rr	15,688	Rr
Mar-2001	185.1	Gr	11,382	Gr	1,945	Rr	1,323	Rr	20,473	Rr
Apr-2001	37.8	Gr	2,250	Gr	2,470	Rr	1,680	Rr	5,140	Rr
May-2001	34.7	Gr	2,136	Gr	1,668	Rr	1,134	Rr	3,295	Rr
Jun-2001	12.0	Gr	712	Gr	2,306	Rr	1,568	Rr	1,518	Rr
Jul-2001	14.3	Gr	877	Gr	2,222	Rr	1,511	Rr	1,802	Rr
Aug-2001	8.2	Gr	501	Gr	1,630	Rr	1,108	Rr	755	Rr
Sep-2001	37.1	Gr	2,207	Gr	1,109	Rr	754	Rr	2,264	Rr

	Monthly Average mean cfs	Total total acre-feet	FW EC mean µS/cm	TDS mean mg/L	Salt load total tons
WY 1997	129.5	93,381	1,300	884	99,334
WY 1998	192.9	136,640	1,185	806	146,403
WY 1999	95.9	69,050	1,427	970	90,132
WY 2000	87.4	63,182	1,455	990	84,197
WY 2001	89.5	64,617	1,696	1,153	92,674

(*) Flow passing Station C is calculated as difference between flows at Stations D and B.

Data Summary

Table 6 and Figure 6 summarize the daily flow and EC of water that passed Station F during the five years of the Project.

No water from the GDA was released into Salt Slough during Water Year 2001. The average flow of water was 185 cfs. The peak flow of 714 cfs occurred on March 8, 2001. Approximately 133,900 acre-feet flowed past this site during this water year.

The flow-weighted average EC of water was 1,350 µS/cm, ranging from 863 to 1,860 µS/cm. The total salt load was 168,700 tons.

The total volume of water in Salt Slough during Water Year 2001 was about 5 percent less than 2000 Water Year. However, the load of salt in the water was similar to the salt load in Water Year 2000 due to slight increase in average electrical conductivity.

Performance

EC and temperature data were lost for 45 days due to equipment failure and vandalism.

Comments

The California Department of Water Resources also measures flow at this site.

Station N

Location	San Joaquin River at Crows Landing, California (USGS 11274550) (CVRWQCB STC504)
Responsibility	US Geological Survey (flow, EC, temp), CVRWQCB (EC, water quality)
Parameters	Stage, electrical conductivity, temperature
Equipment	Nitrogen bubbler pressure transducer, electrical conductivity/temperature sensor, data logger, cellular telephone and modem.

Description

Station N is located at Crows Landing on the San Joaquin River, a few miles downstream of the tributary of the Merced River.

Figure 5. Monthly Flow and Salinity of Water in Mud Slough (Station D)

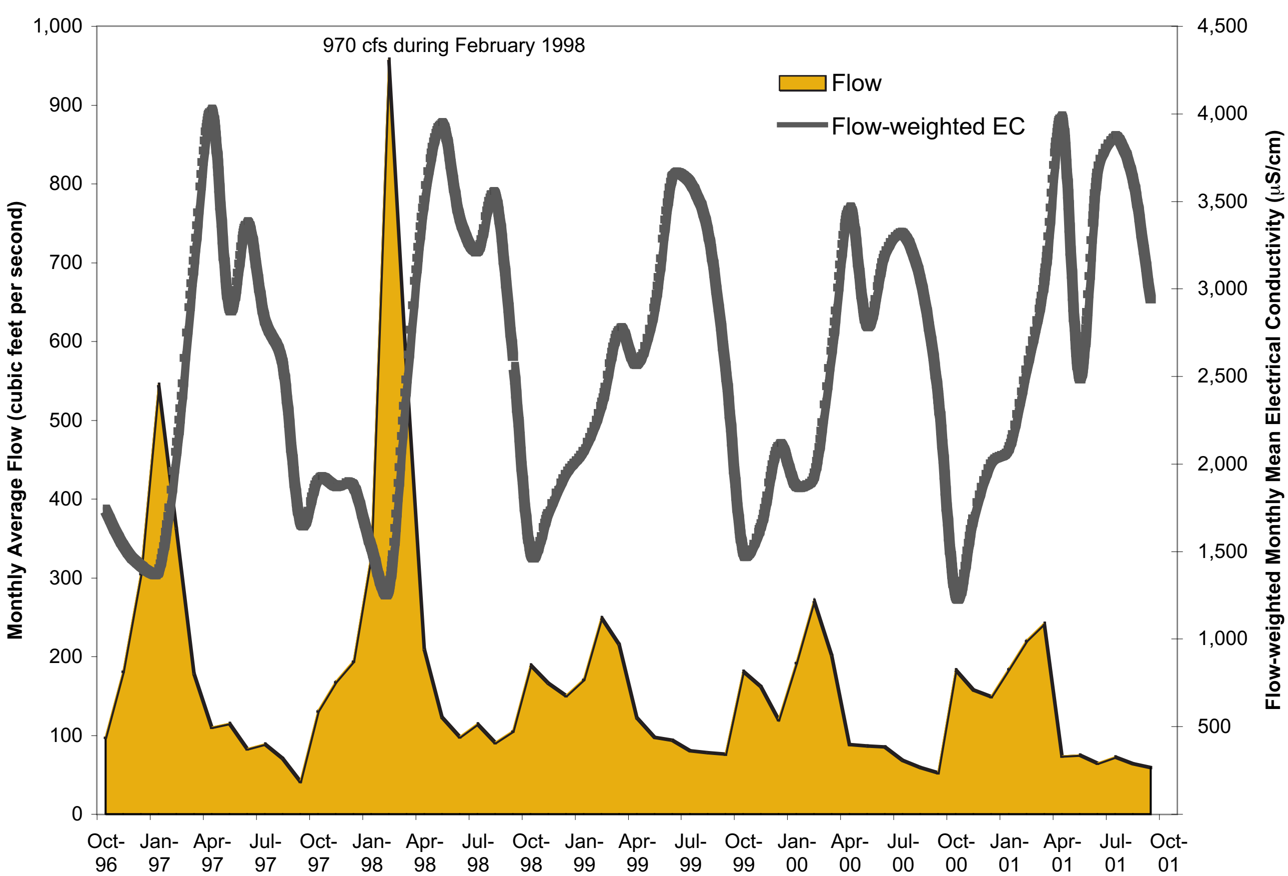


Table 5. Monthly Flow and Salinity of Water in Mud Slough (Station D) WY 1997 - 2001

	Flow				Salinity					
	Monthly Average cfs		Total acre-feet		FW EC µS/cm		TDS mg/L		Salt load tons	
Oct-1996	97.2	G	5,980	G	1,738	Gr	1,199	Gr	9,748	Gr
Nov-1996	181.0	G	10,750	G	1,536	Gr	1,060	Gr	15,496	Gr
Dec-1996	305.0	G	18,750	G	1,418	Gr	978	Gr	24,950	Gr
Jan-1997	545.0	G	33,510	G	1,390	Gr	959	Gr	43,714	Gr
Feb-1997	363.0	G	20,180	G	2,077	Gr	1,433	Gr	39,324	Gr
Mar-1997	178.0	G	10,920	G	3,167	Gr	2,185	Gr	32,460	Gr
Apr-1997	110.0	G	6,550	G	4,018	Gr	2,772	Gr	24,701	Gr
May-1997	115.0	G	7,090	G	2,891	Gr	1,995	Gr	19,227	Gr
Jun-1997	82.5	G	4,910	G	3,378	Gr	2,331	Gr	15,555	Gr
Jul-1997	89.0	G	5,470	G	2,819	Gr	1,945	Gr	14,475	Gr
Aug-1997	70.5	G	4,340	G	2,576	Gr	1,777	Gr	10,483	Gr
Sep-1997	41.6	G	2,480	G	1,672	Gr	1,154	Gr	3,887	Gr
Oct-1997	131.0	G	8,060	G	1,916	Gr	1,322	Gr	14,493	Gr
Nov-1997	168.0	G	9,980	G	1,873	Gr	1,292	Gr	17,530	Gr
Dec-1997	194.0	G	11,960	G	1,873	Gr	1,292	Gr	21,011	Gr
Jan-1998	328.0	G	20,170	G	1,526	Gr	1,053	Gr	28,880	Gr
Feb-1998	958.0	G	53,190	G	1,289	Gr	889	Gr	64,346	Gr
Mar-1998	563.0	G	34,590	G	2,489	Gr	1,717	Gr	80,684	Gr
Apr-1998	209.0	G	12,450	G	3,519	Gr	2,428	Gr	41,113	Gr
May-1998	123.0	G	7,550	G	3,945	Gr	2,722	Gr	27,964	Gr
Jun-1998	97.7	G	5,810	G	3,403	Gr	2,348	Gr	18,562	Gr
Jul-1998	114.0	G	6,980	G	3,218	Gr	2,220	Gr	21,089	Gr
Aug-1998	90.8	G	5,580	G	3,534	Gr	2,438	Gr	18,510	Gr
Sep-1998	105.0	G	6,260	G	2,618	Gr	1,806	Gr	15,382	Gr
Oct-1998	189.0	G	11,610	G	1,495	Gr	1,032	Gr	16,286	Gr
Nov-1998	166.0	G	9,900	G	1,727	Gr	1,192	Gr	16,051	Gr
Dec-1998	150.0	G	9,230	G	1,950	Gr	1,346	Gr	16,883	Gr
Jan-1999	171.0	G	10,520	G	2,083	Gr	1,437	Gr	20,564	Gr
Feb-1999	249.0	G	13,850	G	2,338	Gr	1,613	Gr	30,373	Gr
Mar-1999	215.0	G	13,230	G	2,771	Gr	1,912	Gr	34,411	Gr
Apr-1999	122.0	G	7,240	G	2,572	Gr	1,775	Gr	17,480	Gr
May-1999	97.5	G	5,990	G	2,900	Gr	2,001	Gr	16,314	Gr
Jun-1999	93.5	G	5,570	G	3,644	Gr	2,514	Gr	19,032	Gr
Jul-1999	80.2	G	4,930	G	3,608	Gr	2,490	Gr	16,689	Gr
Aug-1999	77.9	G	4,790	G	3,334	Gr	2,300	Gr	14,980	Gr
Sep-1999	75.7	G	4,500	G	2,558	Gr	1,765	Gr	10,808	Gr
Oct-1999	181.0	G	11,130	G	1,498	Gr	1,034	Gr	15,642	Gr
Nov-1999	162.0	G	9,630	G	1,647	Gr	1,136	Gr	14,885	Gr
Dec-1999	120.0	G	7,360	G	2,109	Gr	1,455	Gr	14,570	Gr
Jan-2000	192.0	G	11,780	G	1,874	Gr	1,293	Gr	20,724	Gr
Feb-2000	271.0	G	15,610	G	1,931	Gr	1,332	Gr	28,291	Gr
Mar-2000	201.0	G	12,360	G	2,653	Gr	1,831	Gr	30,773	Gr
Apr-2000	88.2	G	5,250	G	3,463	Gr	2,389	Gr	17,056	Gr
May-2000	86.5	G	5,320	G	2,791	Gr	1,926	Gr	13,935	Gr
Jun-2000	85.4	G	5,080	G	3,204	Gr	2,211	Gr	15,273	Gr
Jul-2000	68.3	G	4,200	G	3,315	Gr	2,287	Gr	13,055	Gr
Aug-2000	58.9	G	3,620	G	3,059	Gr	2,111	Gr	10,402	Gr
Sep-2000	52.1	G	3,100	G	2,403	Gr	1,658	Gr	6,996	Gr
Oct-2000	183.0	G	11,234	Gr	1,250	G	863	Gr	12,741	Gr
Nov-2000	157.2	G	9,356	Gr	1,696	Gr	1,170	Gr	14,891	Gr
Dec-2000	149.0	G	9,162	Gr	2,011	Gr	1,388	Gr	17,286	Gr
Jan-2001	183.9	G	11,310	Gr	2,090	G	1,442	Gr	21,903	Gr
Feb-2001	220.2	G	12,230	Gr	2,546	Gr	1,757	Gr	29,224	Gr
Mar-2001	241.9	G	14,872	Gr	3,050	G	2,105	Gr	39,046	Gr
Apr-2001	73.6	G	4,380	Gr	3,975	Gr	2,743	Gr	16,336	Gr
May-2001	74.6	G	4,590	Gr	2,492	Gr	1,719	Gr	10,733	Gr
Jun-2001	64.6	G	3,842	Gr	3,670	G	2,532	Gr	13,088	Gr
Jul-2001	72.2	G	4,437	Gr	3,870	G	2,670	Gr	16,043	Gr
Aug-2001	64.1	G	3,941	Gr	3,630	G	2,505	Gr	13,406	Gr
Sep-2001	59.1	G	3,517	Gr	2,946	Gr	2,033	Gr	9,723	Gr

	Monthly Average mean cfs	Total total acre-feet	FW EC mean µS/cm	TDS mean mg/L	Salt load total tons
WY 1997	181.5	130,930	2,390	1,649	254,022
WY 1998	256.8	182,580	2,600	1,794	369,564
WY 1999	140.6	101,360	2,582	1,781	229,871
WY 2000	130.5	94,440	2,496	1,722	201,601
WY 2001	128.6	92,871	2,769	1,910	214,420

Data Summary

Table 7 and Figure 7 summarize the mean daily flow and EC of water that passed Station N during the five years of the Project.

During Water Year 2001, the average flow that passed this site was about 900 cfs. The maximum flow of 2,990 cfs occurred on March 8, 2001. The total amount of water that passed this site was 653,400 acre-feet. The discharge from the GBP was about 4 percent of this flow. The flow-weighted average EC of water that passed Station N was 1,185µS/cm. The load of salt in the water was about 623,600 tons. The discharge from the GBP was about 19 percent of the salt load measured at this site.

Performance

EC and temperature data were lost for 23 days during May 2001 because of vandalism.

Comments

The location is not ideal because it is on a bend in the river. The stage-discharge relationship varies during high flows due to bank erosion and sediment deposit. The logistics for making current meter readings at this site are very difficult at high stages. Current meter readings are taken from a boat.

Other Monitoring Stations

Stations G and H are located on the San Joaquin River. The CVRWQCB collected weekly grab samples at Station G, and the EC of each sample was measured in a laboratory. The CVRWQCB did not collect water quality samples at Station H during Water Year 2001. Flow is not measured at these locations.

The CVRWQCB also collected weekly water quality samples at Stations J, K, L2, and M2 (Camp 13, Agatha, San Luis, and Santa Fe Canals, respectively). The purpose of these sites is to ensure that no agricultural drainage water from the GDA enters wetland supply channels in Grasslands Water District. The EC of each sample was measured in the laboratory. Flow is measured daily at these locations by Grasslands Water District.

Table 8 summarizes EC measurements of water that passed these stations during the five years of the Project. The data shows an increase in salinity as water passes across the southern portion of Grassland Water District. During Water Year 2001, the average salinity of

Figure 6. Flow and Salinity of Water in Salt Slough (Station F)

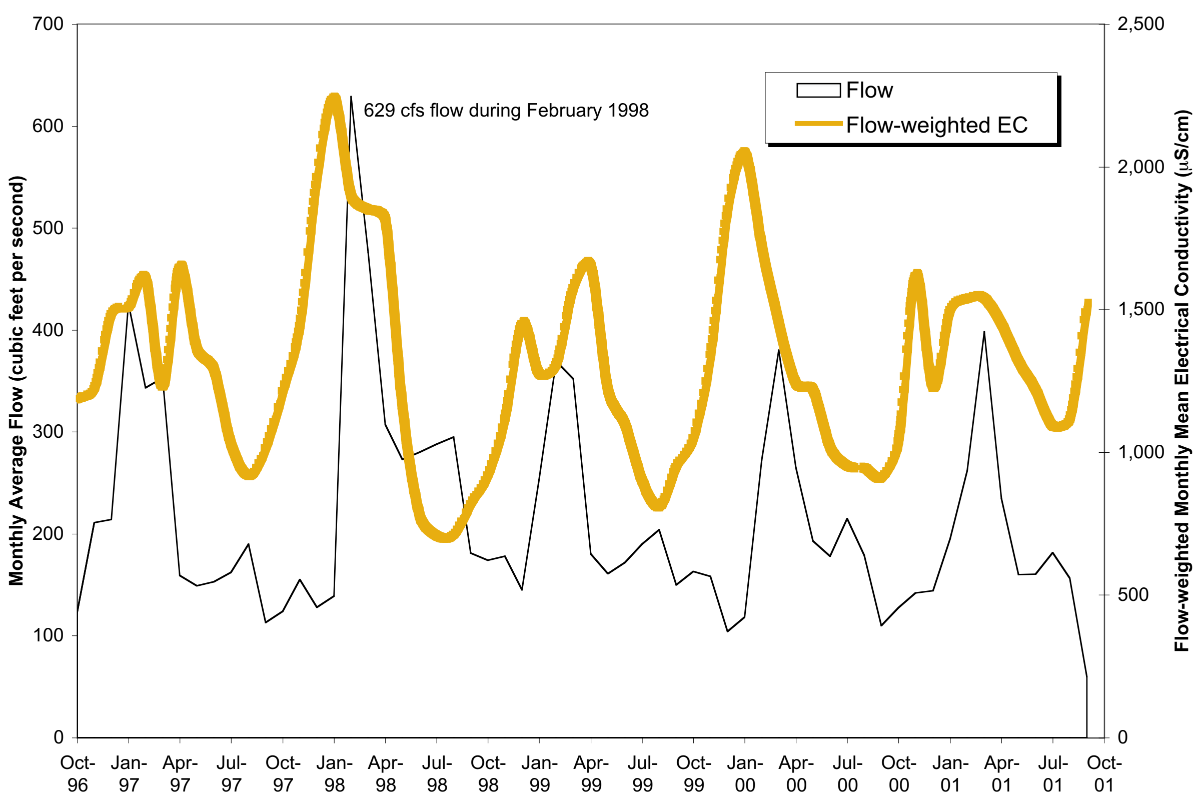


Table 6. Monthly Flow and Salinity of Water in Salt Slough (Station F) WY 1997 - 2001

	Flow				Salinity					
	Monthly Average		Total		FW EC		TDS		Salt load	
	cfs		acre-feet		µS/cm		mg/L	0.68	tons	
Oct-1996	123	G	7,590	G	1,188	Gr	808	Gr	8,342	Gr
Nov-1996	211	G	12,550	G	1,228	Gr	835	Gr	14,256	Gr
Dec-1996	214	G	13,140	G	1,490	Gr	1,013	Gr	17,831	Gr
Jan-1997	426	G	26,160	G	1,511	Gr	1,027	Gr	36,560	Gr
Feb-1997	343	G	19,050	G	1,608	Gr	1,093	Gr	28,323	Gr
Mar-1997	353	G	21,720	G	1,233	Gr	838	Gr	24,764	Gr
Apr-1997	159	G	9,450	G	1,653	Gr	1,124	Gr	14,445	Gr
May-1997	149	G	9,140	G	1,363	Gr	927	Gr	11,523	Gr
Jun-1997	153	G	9,130	G	1,292	Gr	879	Gr	10,903	Gr
Jul-1997	162	G	9,940	G	1,029	Gr	700	Gr	9,459	Gr
Aug-1997	190	G	11,690	G	919	Gr	625	Gr	9,929	Gr
Sep-1997	113	G	6,720	G	1,020	Gr	694	Gr	6,335	Gr
Oct-1997	124	G	7,680	G	1,220	Gr	830	Gr	8,668	Gr
Nov-1997	155	G	9,320	G	1,449	Gr	985	Gr	12,486	Gr
Dec-1997	128	G	7,940	G	1,970	Gr	1,340	Gr	14,466	Gr
Jan-1998	139	G	8,700	G	2,242	Gr	1,525	Gr	18,028	Gr
Feb-1998	629	G	35,030	G	1,901	Gr	1,293	Gr	61,588	Gr
Mar-1998	476	G	29,420	G	1,850	Gr	1,258	Gr	50,326	Gr
Apr-1998	307	G	18,420	G	1,817	Gr	1,236	Gr	30,946	Gr
May-1998	273	G	16,840	G	1,165	Gr	792	Gr	18,148	Gr
Jun-1998	280	G	16,800	G	781	Gr	531	Gr	12,128	Gr
Jul-1998	288	G	17,930	G	708	Gr	481	Gr	11,740	Gr
Aug-1998	295	G	17,250	G	714	Gr	486	Gr	11,391	Gr
Sep-1998	181	G	10,770	G	824	Gr	560	Gr	8,208	Gr
Oct-1998	174	G	10,720	G	925	Gr	629	Gr	9,165	Gr
Nov-1998	178	G	10,570	G	1,123	Gr	764	Gr	10,974	Gr
Dec-1998	145	G	8,930	G	1,454	Gr	989	Gr	11,999	Gr
Jan-1999	253	G	15,490	G	1,276	Gr	868	Gr	18,274	Gr
Feb-1999	369	G	20,490	G	1,311	Gr	891	Gr	24,841	Gr
Mar-1999	352	G	21,620	G	1,580	Gr	1,074	Gr	31,584	Gr
Apr-1999	180	G	10,730	G	1,652	Gr	1,123	Gr	16,396	Gr
May-1999	161	G	9,890	G	1,219	Gr	829	Gr	11,143	Gr
Jun-1999	172	G	10,270	G	1,098	Gr	747	Gr	10,430	Gr
Jul-1999	190	G	11,680	G	901	Gr	613	Gr	9,735	Gr
Aug-1999	204	G	12,520	G	811	Gr	551	Gr	9,387	Gr
Sep-1999	150	G	8,860	G	954	Gr	649	Gr	7,817	Gr
Oct-1999	163	G	10,010	G	1,054	Gr	717	Gr	9,752	Gr
Nov-1999	158	G	9,410	G	1,346	Gr	915	Gr	11,712	Gr
Dec-1999	104	G	6,410	G	1,856	Gr	1,262	Gr	11,010	Gr
Jan-2000	118	G	7,280	G	2,049	Gr	1,393	Gr	13,800	Gr
Feb-2000	272	G	15,670	G	1,724	Gr	1,172	Gr	24,979	Gr
Mar-2000	380	G	23,410	G	1,454	Gr	989	Gr	31,474	Gr
Apr-2000	265	G	15,770	G	1,241	Gr	844	Gr	18,099	Gr
May-2000	193	G	11,840	G	1,219	Gr	829	Gr	13,350	Gr
Jun-2000	178	G	10,600	G	1,019	Gr	693	Gr	9,991	Gr
Jul-2000	215	G	13,190	G	953	Gr	648	Gr	11,626	Gr
Aug-2000	179	G	10,990	G	944	Gr	642	Gr	9,595	Gr
Sep-2000	110	G	6,470	G	913	Gr	621	Gr	5,463	Gr
Oct-2000	127	G	7,831	Gr	1,044	Gr	710	Gr	7,559	Gr
Nov-2000	142	G	8,456	Gr	1,622	Gr	1,103	Gr	12,685	Gr
Dec-2000	144	G	8,858	Gr	1,231	Gr	837	Gr	10,085	Gr
Jan-2001	195	G	11,964	Gr	1,503	Gr	1,022	Gr	16,687	Gr
Feb-2001	262	G	14,563	Gr	1,540	G	1,047	Gr	20,497	Gr
Mar-2001	398	G	24,484	Gr	1,540	G	1,047	Gr	34,001	Gr
Apr-2001	235	G	13,962	Gr	1,450	G	986	Gr	18,739	Gr
May-2001	160	G	9,858	Gr	1,320	G	898	Gr	11,864	Gr
Jun-2001	161	G	9,553	Gr	1,220	G	830	Gr	10,682	Gr
Jul-2001	182	G	11,167	Gr	1,092	Gr	743	Gr	11,276	Gr
Aug-2001	157	G	9,632	Gr	1,120	G	762	Gr	9,708	Gr
Sep-2001	60	G	3,564	Gr	1,520	G	1,034	Gr	4,952	Gr

	Monthly Average mean cfs	Total total acre-feet	FW EC mean µS/cm	TDS mean mg/L	Salt load total tons
WY 1997	216	156,280	1,295	880	192,670
WY 1998	273	196,100	1,387	943	258,123
WY 1999	211	151,770	1,192	811	171,743
WY 2000	195	141,050	1,314	894	170,851
WY 2001	185	133,892	1,350	918	168,735

water in wetlands water supply channels, measured at Station G (Fremont Ford), was 1,514 µS/cm.

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Abbreviations from Tables and Figures:

EC	Electrical Conductivity or Specific conductance
FW	Flow-weighted average concentration
G	US Geological Survey published data
Gr	Monthly average or total calculated from USGS 15 minute data by USBR
L	Lawrence Berkeley Laboratory data
Lr	Monthly average or total calculated from LBL 15 minute data by USBR
R	California Regional Water Quality Control Board (Central Valley Region) data
Rr	Monthly average or total calculated from CVRWQCB data by USBR
S	San Luis & Delta-Mendota Water Authority
Sr	Monthly average or total calculated from SLDMWA data by USBR
TDS	Total Dissolved Solids

Figure 7. Flow and Salinity in the San Joaquin River at Crows Landing (Station N)

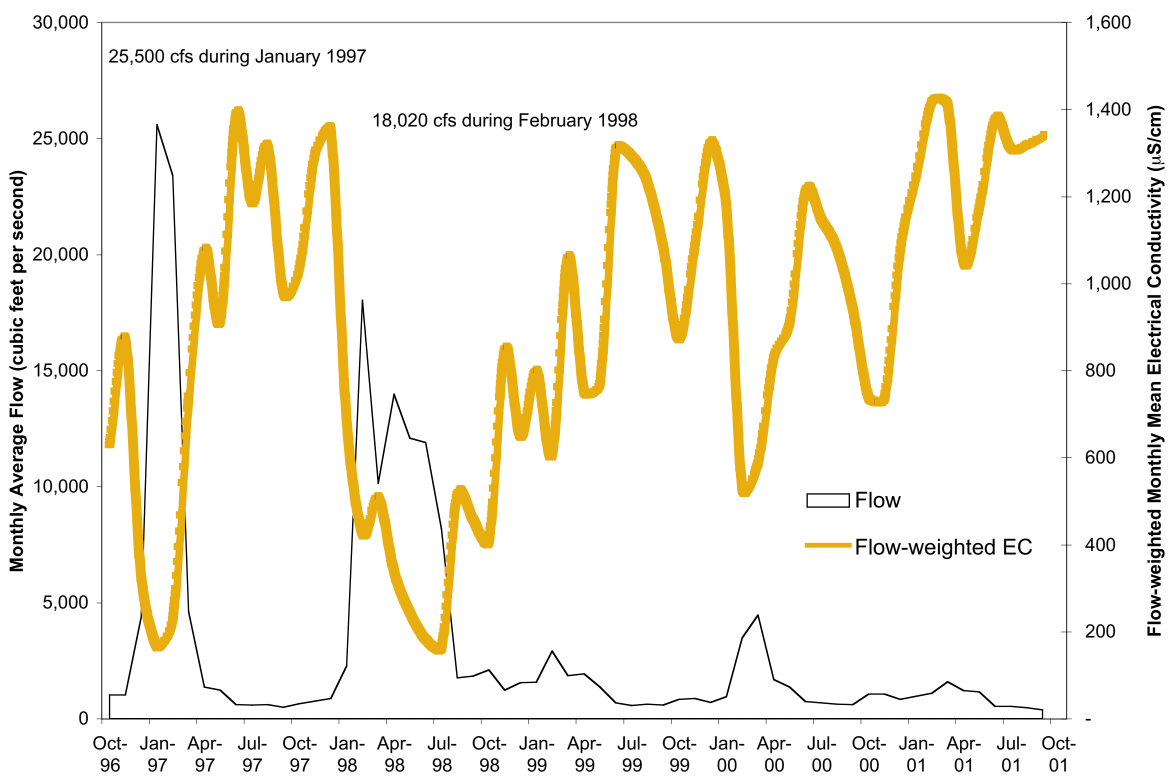

Table 7. Monthly Flow and Salinity of Water in the San Joaquin River at Crows Landing (Station N) WY 1997 - 2001

	Flow		Salinity		
	Monthly Average	Total	FW EC	TDS	Salt load
	cfs	acre-feet	µS/cm	mg/L 0.62	tons
Oct-1996	1,013	62,290	633	392	33,262
Nov-1996	1,027	61,120	869	539	44,792
Dec-1996	4,364	268,300	326	202	73,753
Jan-1997	25,600	1,574,000	166	103	220,954
Feb-1997	23,390	1,299,000	231	143	253,517
Mar-1997	4,614	283,700	745	462	178,110
Apr-1997	1,353	80,480	1,078	668	73,128
May-1997	1,238	76,100	916	568	58,784
Jun-1997	605	35,980	1,390	862	42,186
Jul-1997	583	35,850	1,187	736	35,876
Aug-1997	612	37,630	1,315	815	41,729
Sep-1997	501	29,820	979	607	24,611
Oct-1997	648	39,860	1,037	643	34,861
Nov-1997	751	44,690	1,301	807	49,011
Dec-1997	866	53,260	1,352	838	60,705
Jan-1998	2,270	139,600	685	425	80,603
Feb-1998	18,020	1,001,000	427	265	360,319
Mar-1998	10,130	623,100	508	315	266,927
Apr-1998	13,980	832,100	339	210	238,007
May-1998	12,090	743,600	244	151	152,762
Jun-1998	11,890	707,300	183	113	109,320
Jul-1998	8,176	502,700	164	102	69,341
Aug-1998	1,757	108,100	518	321	47,242
Sep-1998	1,842	109,600	458	284	42,371
Oct-1998	2,092	128,600	410	254	44,509
Nov-1998	1,228	73,090	849	526	52,300
Dec-1998	1,553	95,490	650	403	52,295
Jan-1999	1,562	96,020	800	496	64,734
Feb-1999	2,909	161,500	609	378	82,991
Mar-1999	1,847	113,600	1,062	658	101,750
Apr-1999	1,937	115,200	751	466	72,955
May-1999	1,367	84,070	773	479	54,820
Jun-1999	684	40,690	1,310	812	44,925
Jul-1999	567	34,840	1,293	802	37,983
Aug-1999	615	37,810	1,233	764	39,320
Sep-1999	579	34,440	1,085	673	31,517
Oct-1999	836	51,890	874	542	38,233
Nov-1999	876	52,230	1,091	676	48,036
Dec-1999	695	42,230	1,327	823	47,265
Jan-2000	942	59,110	1,176	729	58,618
Feb-2000	3,480	201,700	530	329	90,098
Mar-2000	4,470	274,900	590	366	136,828
Apr-2000	1,690	100,200	833	516	70,370
May-2000	1,370	84,830	912	565	65,234
Jun-2000	739	43,800	1,214	753	44,821
Jul-2000	675	41,610	1,148	712	40,284
Aug-2000	630	38,800	1,080	670	35,341
Sep-2000	597	36,180	942	584	28,751
Oct-2000	1,050	64,622	738	458	34,895
Nov-2000	1,050	62,365	738	458	38,171
Dec-2000	831	51,105	1,080	670	46,134
Jan-2001	965	59,338	1,250	775	61,973
Feb-2001	1,090	60,745	1,420	880	71,151
Mar-2001	1,590	97,685	1,410	874	108,023
Apr-2001	1,210	71,848	1,051	652	63,652
May-2001	1,160	71,229	1,178	730	70,762
Jun-2001	524	31,187	1,380	856	36,057
Jul-2001	521	32,051	1,310	812	35,425
Aug-2001	472	28,999	1,320	818	32,284
Sep-2001	374	22,251	1,340	831	25,028

	Monthly Average mean cfs	Total total acre-feet	FW EC mean µS/cm	TDS mean mg/L	Salt load total tons
WY 1997	5,408	3,844,270	820	508	1,080,703
WY 1998	6,868	4,904,910	601	373	1,511,470
WY 1999	1,412	1,015,350	902	559	680,098
WY 2000	1,417	1,027,480	976	605	703,876
WY 2001	903	653,425	1,185	734	623,555

Table 8. Electrical Conductivity of Water Passing Other Monitoring Stations (WY 1997 - 2001)

GBP Station	B	G	H	J	K	L	L2	M	M2
Site ID	11262895	MER538	STC512	MER505	MER506	MER532	MER563	MER519	MER545
Location	GBP Discharge San Luis Drain terminus	San Joaquin River at Fremont Ford	San Joaquin River at Hills Ferry	Camp 13	Agatha Canal	San Luis Canal	San Luis Canal, d/s of Splits	Santa Fe Canal	Santa Fe Canal, d/s of Splits
Sample Method	(d)	(wg)	(wg)	(wg)	(wg)	(wg)	(wg)	(wg)	(wg)
Units	µS/cm	µS/cm	µS/cm	µS/cm	µS/cm	µS/cm	µS/cm	µS/cm	µS/cm
Oct-1996	3,948	972	1,268	371	394				
Nov-1996	3,830	1,185	1,345	449	445	934		595	
Dec-1996	4,095	581	773	651	623	953		738	
Jan-1997	4,142	104	274	201	268				
Feb-1997	4,872	101	245	886	2217	1383		1,098	
Mar-1997	4,669	825	1,219	2340	185	1553		1,285	
Apr-1997	5,380	1,838	2,508	1520	540	1400		1,475	
May-1997	4,730	1,766	2,260	779	511	839		839	
Jun-1997	4,642	1,233	1,800	951	466	845		1,052	
Jul-1997	4,206	1,167	1,712	672	415	751		864	
Aug-1997	3,497	1,000	1,495	757	384	749		815	
Sep-1997	3,077	1,383	1,653	445	411	568		576	
Oct-1997	4,425	1,220	1,506	531	501	648		810	
Nov-1997	4,206	1,583	1,715	760	661	760		1,165	
Dec-1997	4,398	1,793	1,858	2638	818	1858		1,892	
Jan-1998	4,919	1,563	1,630	2728	1450	1363		2,738	
Feb-1998	3,397	229	821	2115	2948	1998		2,080	
Mar-1998	4,788	340	843	3055	1285	2078		2,200	
Apr-1998	5,258	145	602	2435	2631	1643		1,668	
May-1998	5,494	95	438	686	415	1292		843	
Jun-1998	4,576	75	269	1167	113	826		454	
Jul-1998	4,020	156	396	190	114	802		483	
Aug-1998	3,983	633	1,138	499	380	858	594	637	1,222
Sep-1998	3,798	608	1,031	280	316	441	406	442	573
Oct-1998	4,738	673	887	267	275	670	415		783
Nov-1998	4,909	1,015	1,234	338	367		435		952
Dec-1998	4,881	606	933	257	256		277		1,338
Jan-1999	4,628	1,268	1,575	701	1221		595		1,810
Feb-1999	4,467	915	1,223	637	883		867		1,908
Mar-1999	5,117	1,486	1,856	794	1471		711		2,042
Apr-1999	5,512	1,546	1,778	779	664		800		1,823
May-1999	4,637	1,518	1,838	442	409		552		955
Jun-1999	4,471	1,458	2,163	526	439		1574		1,084
Jul-1999	4,380	1,136	1,953	521	385		1281		1,125
Aug-1999	3,960	1,022	1,680	551	320		844		1,215
Sep-1999	4,094	1,017	1,488	447	472		507		590
Oct-1999	4,482	1,225		536	509		552		829
Nov-1999	4,253	1,493		614	598		845		1,059
Dec-1999	4,383	2,022		1011	859		817		1,832
Jan-2000	4,355	1,971		743	685		868		1,730
Feb-2000	4,622	1,161		992	1111		1721		2,358
Mar-2000	5,047	829		605	466		694		2,258
Apr-2000	4,863	1,416		661	556		749		1,548
May-2000	4,238	1,430		651	535		822		1,084
Jun-2000	4,190	1,218		596	480		1179		984
Jul-2000	3,899	949		500	411		1265		1,084
Aug-2000	3,485	998		675	397		1148		1,043
Sep-2000	3,792	1,143		419	393		442		493
Oct-2000	3,930	1,210		500	457		1030		648
Nov-2000	3,960	1,384		542	547		2104		966
Dec-2000	3,910	1,708		704	662		1995		1,118
Jan-2001	4,020	1,703		739	753		1519		1,492
Feb-2001	4,245	1,528		684	903		1695		1,675
Mar-2001	5,080	1,324		763	1254		1142		1,785
Apr-2001	5,090	1,668		723	1037		1110		1,723
May-2001	4,488	1,670		647	574		771		1,020
Jun-2001	4,276	1,383		544	577		709		1,370
Jul-2001	3,870	1,285		494	493		726		1,380
Aug-2001	3,500	1,244		619	620		729		1,356
Sep-2001	4,060	2,055		717	696		748		835

	average µS/cm	average µS/cm	average µS/cm	average µS/cm	average µS/cm	average µS/cm	average µS/cm	average µS/cm	average µS/cm
Water Year 1997	4,257	1,013	1,379	835	572	998		934	
Water Year 1998	4,439	703	1,021	1424	969	1214	500	1,284	
Water Year 1999	4,650	1,138	1,551	522	597		738		1,302
Water Year 2000	4,301	1,321		667	583		925		1,359
Water Year 2001	4,202	1,514		640	714		1190		1,281

(d) Flow-weighted averages calculated from USGS 15 minute EC data
(wg) Monthly averages calculated from CVRWQCB lab data of weekly grab samples
Site H monitoring discontinued by Regional Board during WY 2000 and 2001.
Sites L and M moved upstream by the Regional Board after WY 1999 to Sites L2 and M2.

GRASSLAND BYPASS PROJECT

4

Water Quality Monitoring

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Introduction

The monitoring program for the Grassland Bypass Project (GBP), including water quality monitoring, is described in detail in Compliance Monitoring Program for the Use and Operation of the Grassland Bypass Project (USBR et al., 1996). This chapter provides a summary of the water quality monitoring program, modifications to the plan for the fifth year of operation of the GBP (October 1, 2000 to September 30, 2001), and water quality trends observed during five years of operation of the GBP. Detailed water quality data of individual monitoring stations will not be provided in this summary, as the San Francisco Estuary Institute (SFEI) has presented this information in another report (SFEI, 2002).

Monitoring Program

The Central Valley Regional Water Quality Control Board (CVRWQCB) has an on-going water quality monitoring program related to regulatory activities for agricultural subsurface drainage from the Grassland watershed. The water quality monitoring program for the GBP is an adaptation of the CVRWQCB monitoring program. The CVRWQCB conducts most of the water quality sampling, with assistance from the Panoche Drainage District (under contract with the San Luis & Delta-Mendota Water Authority (SLDMWA). The Panoche Drainage District collects samples at Stations A, J, K, L2, and M2. Samples are transferred to and processed by the CVRWQCB and analyzed by its contract laboratories. The CVRWQCB conducts quality assurance (QA) reviews of the data before submitting them to the SFEI for reporting. However, all CVRWQCB data are provisional and subject to change until the CVRWQCB approves its annual agency report on the water year (WY) 2001 monitoring results.

Monitoring Objectives

The water quality monitoring program was designed to provide data for evaluating compliance with commitments in the Project Waste Discharge Requirements, the Use Agreement, and associated documents. The commitments include:

- Monthly and annual selenium load limits on discharges
- No degradation of the San Joaquin River water quality relative to the pre-Project-condition
- Cessation of discharge of agricultural subsurface drainage to the wetland channels
- Management of flows in the San Luis Drain (SLD) so as to not mobilize channel sediments
- The Monitoring Program was also designed to verify the validity of assumptions expressed in documents associated with the GBP. The assumptions include:
- The GBP is expected to result in selenium concentrations less than 2 μg/L in approximately 93 miles of wetland water supply channels.
- The increased frequency of exceeding selenium water quality objectives in Mud Slough (north) will be offset by a reduction of exceedances in Salt Slough.

In addition, the Monitoring Program was intended to provide data to be used to assess spatial and temporal trends in water quality parameters of concern and to characterize habitats in which biological samples were collected.

Sampling Locations

Monitoring was to be conducted in four areas: the SLD, Mud Slough (north), the San Joaquin River, and the Grassland wetland water supply channels, including Salt Slough. Table 1 summarizes the Monitoring Program, and sampling locations are depicted in Figure 2 in Chapter 1.

Frequency of Sampling

The frequency of sampling is outlined in Table 1. Weekly composite samples were collected at Station A (inflow to the SLD). Daily composite samples were collected at Station B (discharge from the SLD), and at Station N (San Joaquin River at Crows Landing). At Station A, daily samples were composited into a weekly sample to be used along with continuous flow data to calculate weekly selenium load inflow to the SLD. At Station B, daily composite samples along with continuous flow data were used to calculate daily selenium load discharge to Mud Slough (north). At Station N, daily composite samples were collected to allow the CVRWQCB to calculate loads and evaluate progress toward compliance with Basin Plan water quality objectives. The compliance date at Station N for the selenium water quality objective (5 μg/L 4-day average) during normal and wet years is October 1, 2005, and during critical years is October 1, 2010 (CVRWQCB,

Table 1. Summary of Water Quality Monitoring Plan

Location	Site	Description	Purpose	Analytical Parameter	Frequency	Sampling Methodology
San Luis Drain	A	inflow to SLD	water quality of inflow (Se and TSS)	Se, B, EC	weekly composite	auto-sampler
				EC, TSS	weekly	mid-channel, depth integrated
	B	discharge from SLD	water quality of discharge (Se and TSS) (for Se load calculation)	Se, B, EC	daily composite	auto-sampler
				Se, B, EC, TSS	weekly	mid-channel, depth integrated
Mud Slough (north)	C	upstream of SLD discharge	Mud Slough (north) base water quality prior to receiving drainage discharges	Se, B, EC	weekly	grab
	D	downstream of discharge	Mud Slough (north) water quality as impacted by drainage discharge	Se, B, EC	weekly	mid-channel, depth integrated
	I/I2	back water	water quality impact of Mud Slough (north) flooding in Kesterson Refuge	Se, B, EC	annually	N/A
Wetland Channels	F	Salt Slough	water quality of habitat and to track improvements in former drainage conveyance channel	Se, B, EC	weekly	grab
	J	Camp 13	verify no discharge of drainage provision	Se, B, EC	weekly	grab
	K	Agatha Canal	verify no discharge of drainage provision	Se, B, EC	weekly	grab
	L2	San Luis Canal	water quality of wetland water supply channel	Se, B, EC	weekly	grab
	M2	Santa Fe Canal	water quality of wetland water supply channel	Se, B, EC	weekly	grab
San Joaquin River	G	at Fremont Ford (upstream of drainage inflow)	track improvements in former drainage conveyance channel and characterize water quality of habitat	Se, B, EC	weekly	grab
	H	at Hill's Ferry (downstream of drainage inflow)	intended to represent water quality of river most impacted by drainage discharge	Se, B, EC	discontinued; determined to be downstream of seasonal Merced River inflows	grab
	N	at Crows Landing (downstream of Merced River confluence)	characterize water quality of habitat	Se, B, EC Se, B, EC	daily composite weekly	auto-sampler grab

1998a). Since the objective is based on a 4-day average concentration, consecutive daily samples are required at this station. The remaining stations were sampled on a weekly basis.

Sampling Methodology

Three types of sampling techniques were utilized, depending on the frequency of sampling and data needs: auto-sampler, mid-channel depth-integrated, and grab sample from channel bank. Auto-samplers were used to collect daily and weekly composite samples because of the remoteness of the station and frequency of sampling. At Stations A, B, and D, structures such as a bridge or platform over the channel permitted the collection of mid-channel, depth-integrated samples. At other stations, a grab sample was collected from the stream bank. With respect to stream hydrology, lateral and vertical homogeneity was assumed for dissolved constituents at all sampling stations.

Modifications to the Water Quality Monitoring Program

During the previous four years of the GBP, a number of issues were resolved with respect to the water quality monitoring program. These modifications and clarifications to the monitoring program are discussed in the first four Annual Reports (USBR, 1998 and SFEI, 1999, 2000, and 2001).

During the fourth year of the GBP it was decided that water quality monitoring at Station H would be conducted by the SLDMWA. The results of the monitoring would be used in conjunction with the biological monitoring portion of the GBP. As the data were collected separate from the water quality monitoring program, the data are not included in this chapter. The data are presented in Chapter 1 of this report.

Water Quality Trends

Detailed water quality data for each monitoring station are presented in the Grassland Bypass Project Annual Narrative and Graphical Summary, October 2000 to September 2001 (SFEI, 2002). Thus, this presentation will be limited to major water quality trends and findings for the five years of operation of the GBP. Of primary interest are selenium concentrations in the San Joaquin River and water quality trends in Mud Slough (north). Also of interest are sporadic exceedances in the wetland channels of selenium water quality objectives established in the Water Quality Control Plan for the Sacramento/San Joaquin River Basins.

San Joaquin River

The Water Quality Control Plan for the Sacramento River and San Joaquin River Basins (Basin Plan) contains a schedule for compliance with the 5 µg/L (4-day average) selenium water quality objective and performance goals. The compliance date is either October 1, 2005 or October 1, 2010, depending on water year type (wet, dry, etc.) (Table 2). Compliance with selenium water quality objectives and performance goals specified in the Basin Plan is measured at Station N.

Figure 1 depicts selenium concentrations in the San Joaquin River at monitoring Stations G (weekly grab) and N (4-day average) for WYs 1997 through 2001. The water quality objective is depicted in Figure 1 for comparison purposes. Station G is located at Fremont Ford, upstream of the Mud Slough (north) inflow to the San Joaquin River. Because this station is located upstream of drainage discharges from the GBP service area (except during flood events when drainage has occasionally been routed to Salt Slough), selenium concentrations are relatively low, and have remained below 2 µg/L since the beginning of the GBP.

Station N is located downstream of the GBP discharges conveyed by Mud Slough (north) and the Merced River inflow to the San Joaquin River. Merced River inflows dilute the upstream selenium contributions (CVRWQCB, 2002). Selenium concentrations frequently exceeded a 5 µg/L (4-day average) during WY 1997, but remained below 10 µg/L. In contrast, selenium concentrations remained below a 5 µg/L (4-day average) during WY 1998. During WY 1999, selenium concentrations exceeded a 5 µg/L (4-day average) during the months of June, July, and August, but remained below 7 µg/L. During WY 2000, selenium concentrations exceeded a 5 µg/L (4-day average) during the month of June, but remained below 6µg/L. During WY 2001, selenium concentrations were above 5µg/L for short periods of time during the months of March, April, June and July. The maximum concentration observed in the San Joaquin River was 5.9 µg/L at Station N on June 16.

On October 1, 2002 a performance goal of either 5 µg/L or 8 µg/L monthly mean selenium concentration (depending on water year type) becomes effective in the San Joaquin River below the confluence with the Merced River. Figure 2 depicts monthly mean selenium concentrations at Station N for WYs 1997 through 2001. With

Figure 1. Selenium Concentration in the San Joaquin River, Water Years 1997 through 2001

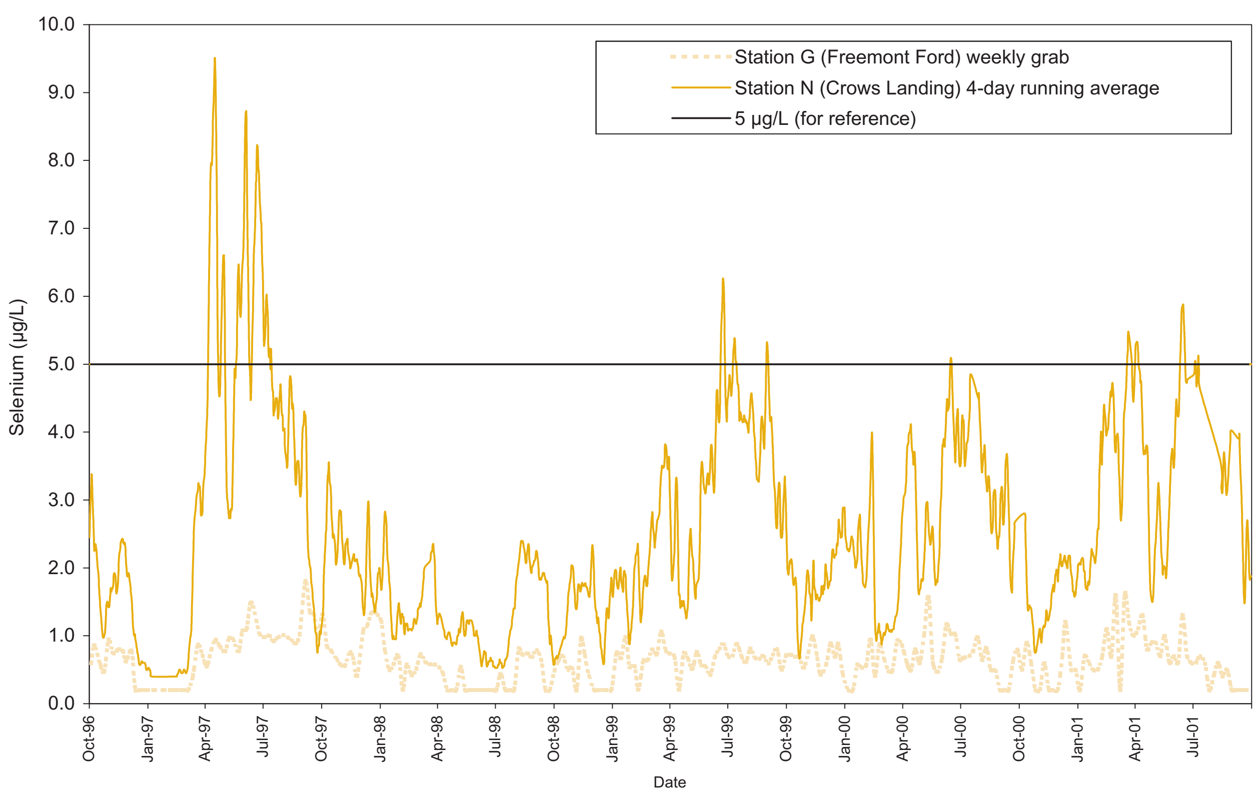


Table 2. Summary of Selenium Water Quality Objectives and Compliance Time Schedule

[Selenium Water Quality Objectives (in bold) and Performance Goals (in italics)]

Water Body/Water Year Type [1]	1 October, 1996	1 October, 2002	1 October, 2005	1 October, 2010
San Joaquin River below the Merced River; Above Normal, and Wet Water Year Types		*5 μg/L monthly mean*	***5 μg/L 4-day average***	
San Joaquin River below the Merced River; Critical, Dry, and Below Normal Water Year Types		*8 μg/L monthly mean*	*5 μg/L monthly mean*	***5 μg/L 4-day average***
San Joaquin River from Sack Dam to the Merced River				***5 μg/L 4-day average***

[1] The water year classification will be established using the best available estimate of the 60-20-20 San Joaquin Valley water year hydrologic classification (as defined in Footnote17 for Table 3 in the State Water Resources Control Board's *Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary*, May 1995) at the 75% exceedance level using data from the Department of Water Resources Bulletin 120 series. The previous water year's classification will apply until an estimate is made of the current water year.

the exception of two months during the wet Water Year 1997, monthly mean selenium concentrations have not exceeded 5 μg/L at Station N. Starting on October 1, 2002, the applicable performance goal for a dry year, such as WY 2001, will be an 8 μg/L monthly mean selenium concentration. Monthly mean selenium concentrations during WY 2001 did not exceed 5μg/L. Thus, it appears that the GAF have demonstrated the capability of meeting these performance goals ahead of schedule.

The Basin Plan and the GBP Waste Discharge Requirements (WDRs) prohibit discharge of selenium from agricultural subsurface drainage systems in the Grassland Watershed to the San Joaquin River in amounts exceeding 8,000-pounds per year. Calculations using daily selenium data, preliminary USGS flow data, and the load calculation methods found in CVRWQCB (1998b) indicate that the annual selenium load measured at Station N during WY 2001 was well below the 8,000-pound annual load limit for the Grassland Watershed.

Wetland Channels

Monthly mean selenium concentrations in the wetland channels for WY 2001 are depicted in Figure 3. The monthly mean 2 μg/L selenium objective was met during all months in Salt Slough. The monthly mean 2μg/L selenium objective was exceeded in March and April at Station J, February through April at Station K, November through April at Station L2, and February and April at Station M2. The maximum observed monthly mean concentrations of 4.1 μg/L at Station J, 5.1 μg/L at Station K, 4.5 μg/L at Station L2, and 2.7 μg/L at Station M2, however, are substantially lower than pre-Project concentrations (CVRWQCB, 1998c).

Regional Board staff conducted preliminary investigations on the potential sources of selenium, which are detailed in two separate reports (CVRWQCB, 2000 and CVRWQCB, 2002). In summary, primary sources of selenium to the channels were determined to be diversions from the 94,000-acre Drainage Project Area (DPA) (both stormwater flows and seepage from control gates), supply water, subsurface agricultural drainage from areas outside of the DPA, tailwater and local groundwater. To address the first source, diversions from the DPA, the Grassland Area Farmers (GAF) developed a stormwater management plan, and internal control gates were sealed. These actions appear to have controlled peaks of selenium previously observed during storm events.

Despite the stormwater management plan and control gate modifications made by the GAF, selenium concentrations have continued to sporadically exceed the 2μg/l monthly mean selenium objective in the wetland

Figure 2. Monthly Mean Selenium Concentration at Crows Landing, Water Years 1997 through 2001

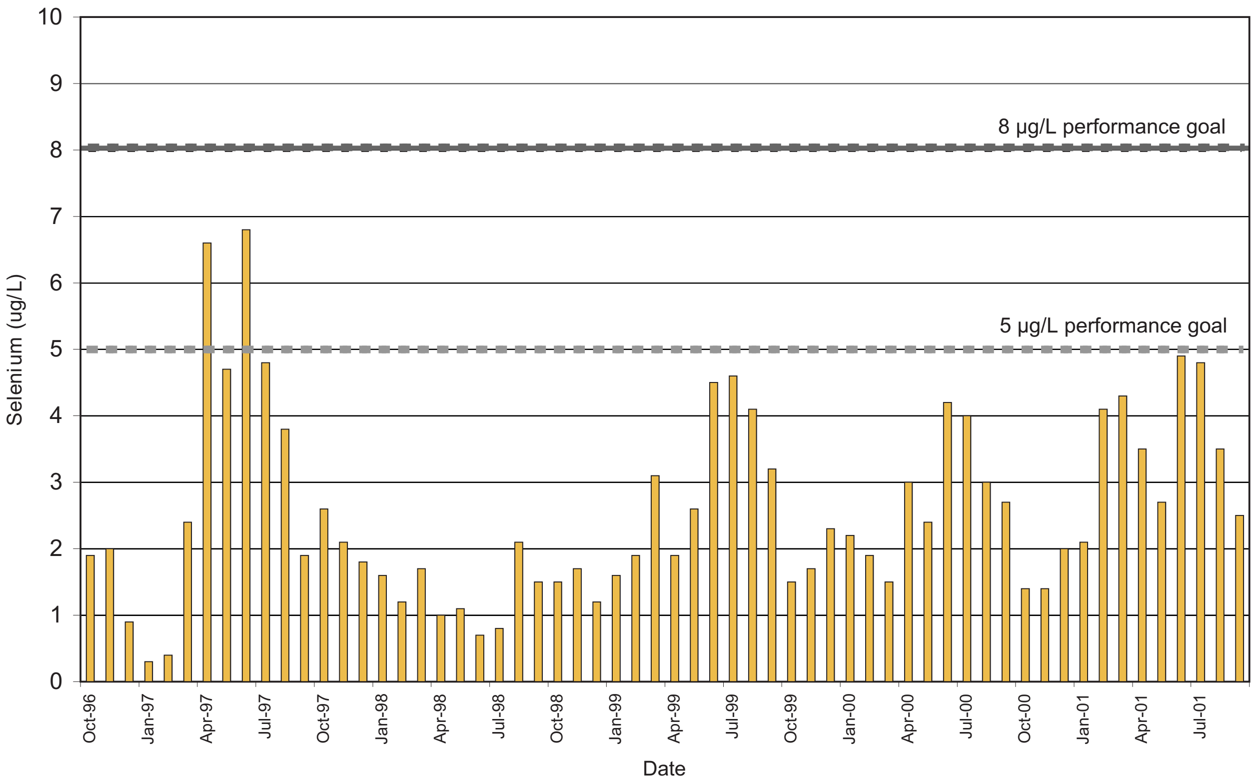


Figure 3. Mean Monthly Selenium Concentration in the Wetland Channels October 1, 2000 to September 30, 2001

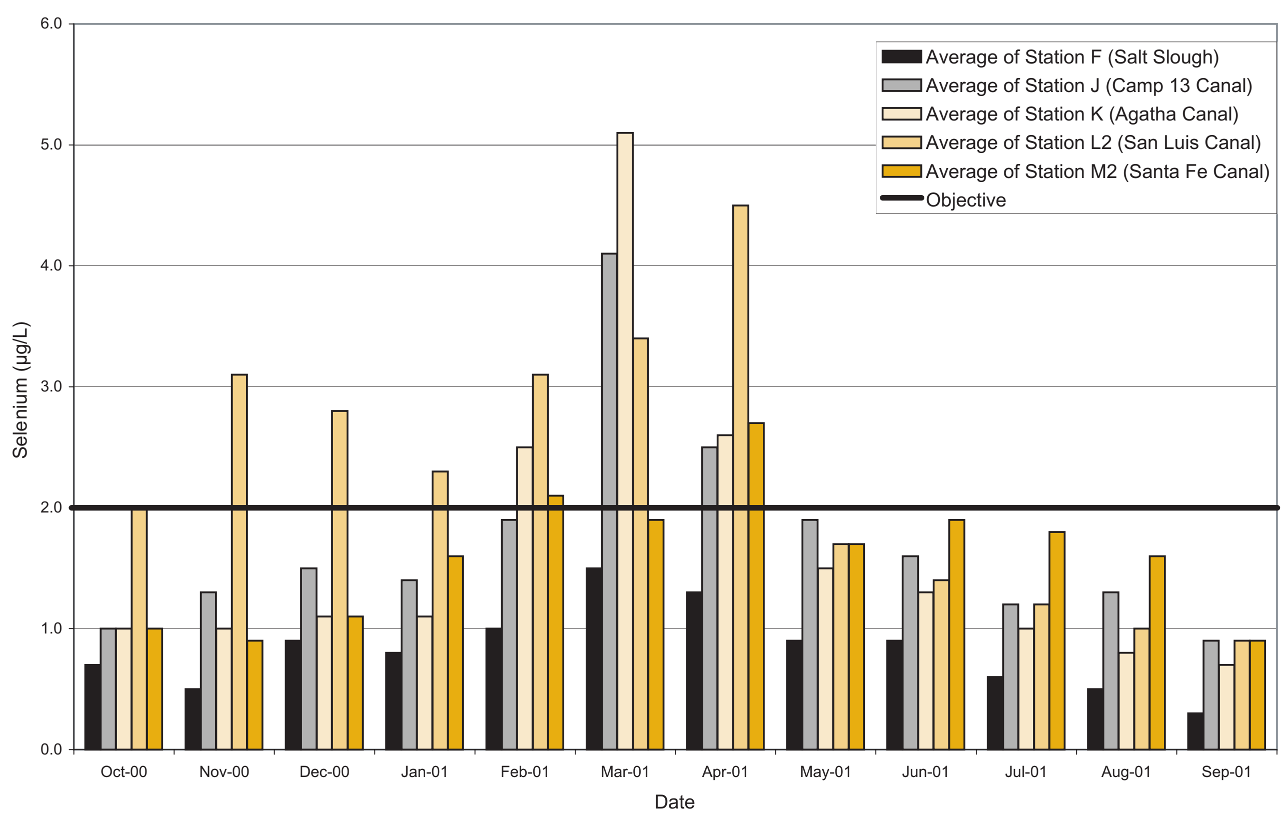
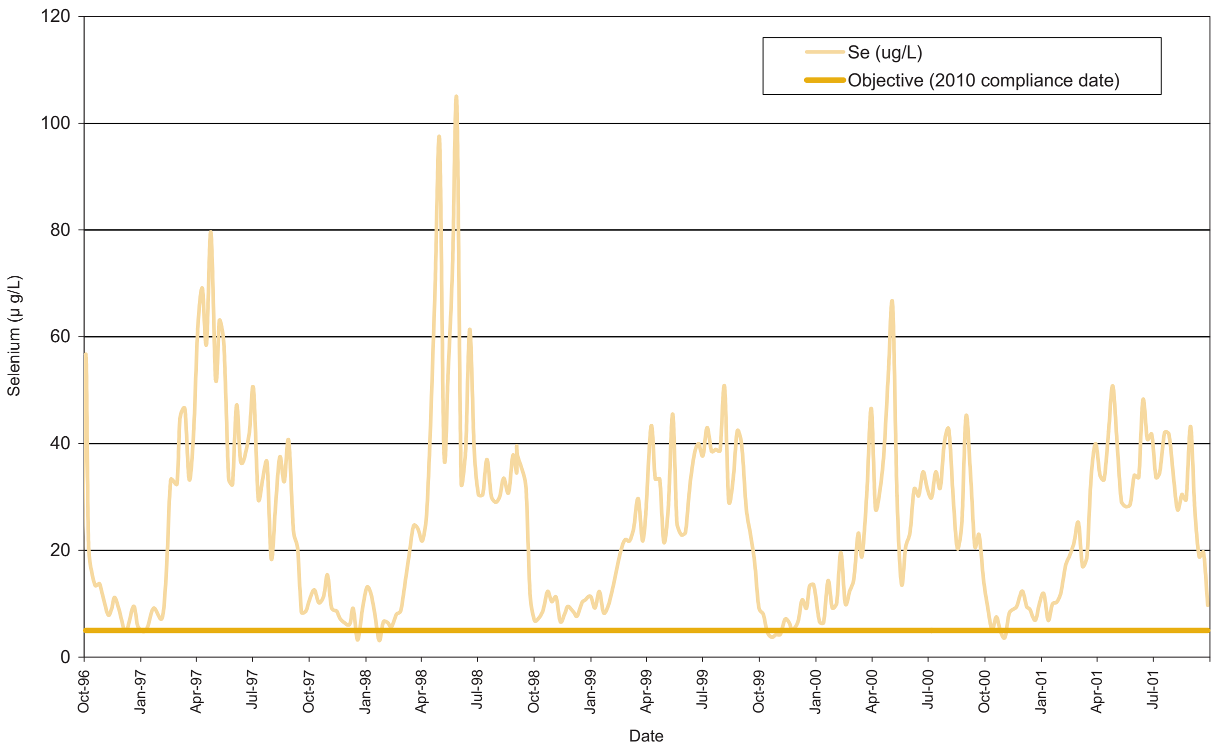


Figure 4. Selenium Concentration in Mud Slough (north) downstream of SLD WYs 1997 through 2001



channels, particularly from the pre-irrigation season through the early irrigation season (February through April). As a result of the continued elevated selenium concentrations, staff focused the ongoing investigations on potential selenium sources outside of the GBP area: supply water and subsurface agricultural drainage from outside of the GBP service area. Results are currently under review and will be used to direct the ongoing investigation during Water Year 2002.

Mud Slough (North)

Results of weekly grab sampling for selenium at Station D, Mud Slough (north) downstream of the SLD, are depicted in Figure 4. Selenium concentration distributions as a function of time were similar for all water years. Selenium concentrations tend to be lowest from the fall through early winter (non-irrigation period) and highest during the irrigation period, which commences in mid winter (pre-plant irrigation) and lasts through the summer. During Water Year 2001, selenium concentrations in Mud Slough (north) downstream of the SLD ranged from 3.7 μg/L in November, to 50.8 μg/L in April. Water quality in Mud Slough (north) downstream of the SLD is dominated by the GBP drainage discharge. For comparison purposes, the 5 μg/L (4-day average) selenium water quality objective, which applies October 1, 2010 for Mud Slough (north), is noted on Figure 4. Selenium concentrations regularly exceeded 5 μg/L in Mud Slough (north) downstream of the SLD inflow. Upstream of the drainage discharge, the concentration of selenium was usually below 2 μg/L, and the maximum observed selenium concentration was 2.2μg/L (Figure 5).

Boron Water Quality Objectives

Mean monthly boron objectives and WY 2001 boron concentrations for Mud Slough, Salt Slough, and the San Joaquin River are depicted in Table 3. Exceedances of the 2.0 mg/L objective occurred at Station C in April and at Station D from March through September. The 1.0 mg/L objective was exceeded at Station N during February and March, and the 0.8 mg/L objective was exceeded at Station N during March and April and from June through August. Sources of boron extend throughout the San Joaquin Basin and are not restricted to the GBP (CVRWQCB, 2002). The CVRWQCB is concurrently conducting a separate effort to control salt and boron loading to the lower San Joaquin Basin.

Conclusions

Five years of GBP monitoring have shown that selenium concentrations in the San Joaquin River are a function of location in the River with respect to discharge points and tributary inflows, and of the assimilative capacity of the River. The lowest selenium concentrations in the San Joaquin River are upstream of Mud Slough (north) inflows. Mud Slough (north) inflow contains relatively high concentrations of selenium. The Merced River dilutes the San Joaquin River with respect to selenium. Selenium concentrations in the San Joaquin River at Station N, however, remain elevated relative to the background condition in the San Joaquin River at Station G.

The 2 μg/L monthly mean selenium water quality objective was exceeded in four of the wetland supply channels during WY 2001. The maximum monthly mean observed was 5.1μg/L at Station K (Agatha Canal) in March. A number of sources may contribute to the exceedances of selenium water quality objectives in the wetland channels, including agricultural subsurface drainage from areas outside the GBP being discharged to the channels upstream of the wetlands. CVRWQCB staff is conducting ongoing investigations focusing on identifying sources of selenium that contribute to exceedances of the selenium water quality objective in the wetland supply channels. The results of these investigations are detailed in separate reports that are available from the Regional Board. The CVRWQCB is evaluating control actions to reduce selenium concentrations in the wetland channels.

The water quality of Mud Slough (north) downstream of the SLD inflow is governed by the GBP drainage discharge and fluctuates widely. Selenium concentrations tend to be lowest from the fall through early winter (non-irrigation period) and highest during the irrigation period, which commences in mid winter (pre-plant irrigation) and lasts through the summer. Selenium concentrations regularly exceeded 5 μg/L in Mud Slough (north) downstream of the SLD inflow, and reached an observed maximum concentration of 50.8 μg/L in April 2001. Upstream of the drainage discharge, the concentration of selenium was usually below 2 μg/L.

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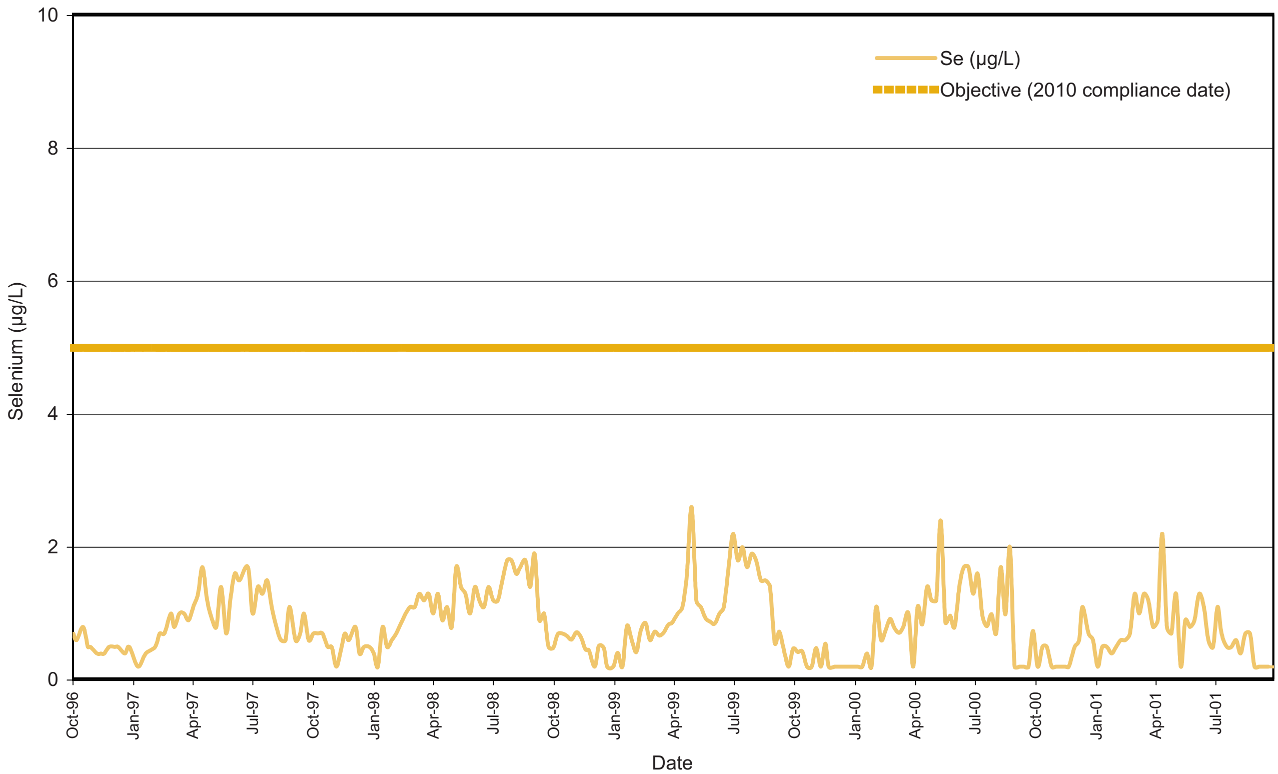
Table 3. Boron Water Quality Objective Exceedances in the Grassland Watershed and San Joaquin River: Water Year 2001.

Station ID	Description	Mean Monthly Concentration (mg/L)												Monthly WQO
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
C	Mud Slu (N) upstrm of SLD Discharge	a	a	a	a	a	**2.0**	**2.2**	**1.3**	**2.0**	**1.8**	**1.5**	**0.67**	2.0
D	Mud Slu (N) dwnstrm of SLD Discharge	a	a	a	a	a	**4.0**	**5.2**	**4.7**	**6.4**	**6.1**	**5.3**	**4.8**	2.0
F	Salt Slough at Lander Avenue	a	a	a	a	a	**1.0**	**0.94**	**0.56**	**0.50**	**0.53**	**0.46**	**0.68**	2.0
G	SJR at Fremont Ford	a	a	a	a	a	**0.60**	**0.80**	**0.58**	**0.50**	**0.56**	**0.45**	**0.68**	2.0
N	SJR at Crows Landing Weekly Grab Samples	**0.40**	**0.47**	**0.72**	**0.84**	**1.1**	**1.1**	**0.87**	**0.58**	**1.0**	**1.1**	**1.0**	**0.77**	1.0/0.8[1]
N	SJR at Crows Landing Daily Autosamples	**0.41**	**0.50**	**0.73**	**0.85**	**1.1**	**1.1**	**0.83**	**0.59**	**1.1**	**1.2**	**1.0**	**0.73**	1.0/0.8[1]

[shaded] = water quality objective exceedance
WQO = water quality objective in mg/L

a = objective only applies 15 March through 15 September
[1] = 1.0 mg/L applies 16 September through 14 March
0.8 mg/L applies 15 March through 15 September

Figure 5. Weekly Grab Selenium Concentration at Station C (Mud Slough (north) upstream of SLD) for WYs 1997, 1998, 1999, 2000, and 2001



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G R A S S L A N D B Y P A S S P R O J E C T

5

Flow, Salt and Selenium Mass Balances in the San Luis Drain

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Summary

Although lined with concrete along the 28 mile reach utilized by the Grassland Bypass Project (GBP), about 1,230 acre-feet of water entered the San Luis Drain (SLD) between Stations A and B during the 2001 Water Year. There was a net reduction in salt load of about 5,400 tons (4 percent) and a net decrease of about 116 pounds of selenium (about 3 percent) between the monitoring sites during WY 2001.

The reason for differences in flow may be due to water seeping into the SLD when adjacent wetlands are flooded. The difference in loads may be due to analytical errors. Tables 1, 2, and 3 summarize monthly flows, salt loads, and selenium loads that passed Stations A and B during the five years of the Project. Table 4 summarizes the effects of rainfall and evapotranspiration on the volume of water in the SLD.

Note that the historical concentration and load values have been updated and differ from those in the 1999 Annual Report and errata sheets.

Background

Seepage into the SLD most likely occurs through cracks and one-way weep valves that equalize hydraulic pressure to prevent the concrete lining from buckling. Along the SLD, the water surface elevation of adjacent wetlands, when flooded in the fall and winter, is often higher than the elevation of water in the SLD.

Leakage from the SLD can occur where the concrete lining is fractured or between adjacent concrete panels. Other losses from the SLD include direct evaporation of water and evapotranspiration by algae and aquatic plants.

Flow Differences between Stations A and B

Table 1 summarizes the amount of water that flowed past Stations A and B during the five years of the Project. Figure 1 compares the monthly flows of water that passed Stations A and B for all five years of the GBP.

About 1,230 acre-feet more water flowed past Station B than Station A during WY 2001. This occurred during October through January while adjacent wetlands were flooded. Similar increases have occurred in the autumn and winter of previous years.

Summers Engineering analyzed this situation. Table 4 calculates the net discharge in acre-feet per month by taking into account precipitation and evaporation from the surface area of the Drain. Once precipitation and evaporation are accounted for, the difference in flow between Stations A and B ranges from −3 percent to +4 percent for February through August 2001

Figure 1. Comparison of Flows in the San Luis Drain WY 1997 - 2001

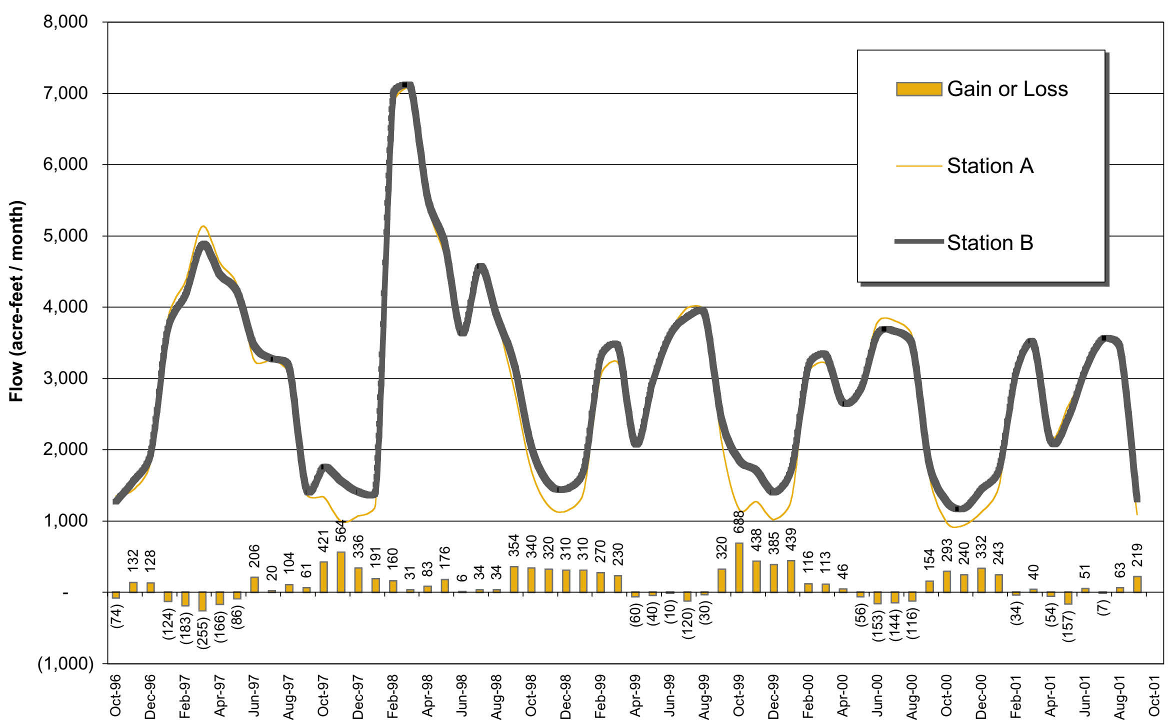

Table 1. Comparison of Flow Measurements

	Monthly Average Flow Station A cfs		Station B cfs		Station A af/month	Station B af/month	Difference	Percent of Station B
Oct-1996	22.0	Lr	20.8	Lr	1,350	1,276	(74)	-6%
Nov-1996	24.2	Lr	26.4	Lr	1,437	1,569	132	8%
Dec-1996	29.6	Lr	31.7	Lr	1,818	1,946	128	7%
Jan-1997	62.2	Lr	60.2	Lr	3,827	3,703	(124)	-3%
Feb-1997	78.4	Lr	75.1	Lr	4,356	4,173	(183)	-4%
Mar-1997	83.5	Lr	79.3	Lr	5,131	4,876	(255)	-5%
Apr-1997	77.6	Lr	74.8	Lr	4,619	4,453	(166)	-4%
May-1997	69.9	Lr	68.6	Lr	4,301	4,215	(86)	-2%
Jun-1997	54.6	Lr	58.1	Lr	3,251	3,457	206	6%
Jul-1997	53.0	Lr	53.3	Lr	3,257	3,277	20	1%
Aug-1997	49.7	Lr	51.4	Lr	3,055	3,159	104	3%
Sep-1997	23.3	Lr	24.3	Lr	1,384	1,445	61	4%
Oct-1997	21.7	Lr	28.6	Lr	1,335	1,756	421	24%
Nov-1997	16.7	Lr	26.2	Lr	994	1,558	564	36%
Dec-1997	17.4	Lr	22.9	Lr	1,070	1,406	336	24%
Jan-1998	20.0	Lr	23.1	Lr	1,230	1,421	191	13%
Feb-1998	123.0	Lr	125.9	Lr	6,833	6,993	160	2%
Mar-1998	115.1	Lr	115.6	Lr	7,075	7,106	31	0%
Apr-1998	91.5	Lr	92.9	Lr	5,444	5,527	83	2%
May-1998	76.7	Lr	79.5	Lr	4,714	4,890	176	4%
Jun-1998	61.0	Lr	61.1	Lr	3,629	3,635	6	0%
Jul-1998	73.8	Lr	74.3	Lr	4,538	4,572	34	1%
Aug-1998	62.6	Lr	63.1	Lr	3,849	3,883	34	1%
Sep-1998	47.7	Lr	53.7	Lr	2,839	3,193	354	11%
Oct-1998	27.6	G	33.2	G	1,700	2,040	340	17%
Nov-1998	20.4	G	25.7	G	1,210	1,530	320	21%
Dec-1998	18.6	G	23.6	G	1,140	1,450	310	21%
Jan-1999	22.7	G	27.6	G	1,390	1,700	310	18%
Feb-1999	54.8	G	59.6	G	3,040	3,310	270	8%
Mar-1999	52.3	G	56.0	G	3,220	3,450	230	7%
Apr-1999	35.9	G	34.9	G	2,140	2,080	(60)	-3%
May-1999	48.7	G	48.2	G	3,000	2,960	(40)	-1%
Jun-1999	60.9	G	60.7	G	3,620	3,610	(10)	0%
Jul-1999	64.8	G	63.0	G	3,990	3,870	(120)	-3%
Aug-1999	64.1	G	63.6	G	3,940	3,910	(30)	-1%
Sep-1999	34.9	G	40.3	G	2,080	2,400	320	13%
Oct-1999	18.9	S	30.0	G	1,162	1,850	688	37%
Nov-1999	21.4	S	28.8	G	1,273	1,710	438	26%
Dec-1999	16.5	S	22.8	G	1,015	1,400	385	28%
Jan-2000	20.8	S	27.9	G	1,281	1,720	439	26%
Feb-2000	53.4	S	55.5	G	3,074	3,190	116	4%
Mar-2000	52.3	S	54.2	G	3,217	3,330	113	3%
Apr-2000	43.9	S	44.8	G	2,614	2,660	46	2%
May-2000	47.3	S	46.4	G	2,906	2,850	(56)	-2%
Jun-2000	63.6	S	61.0	G	3,783	3,630	(153)	-4%
Jul-2000	61.9	S	59.5	G	3,804	3,660	(144)	-4%
Aug-2000	58.3	S	56.5	G	3,586	3,470	(116)	-3%
Sep-2000	27.5	S	30.1	G	1,637	1,790	154	9%
Oct-2000	15.8	S	20.6	G	972	1,265	293	23%
Nov-2000	15.8	S	19.8	G	940	1,180	240	20%
Dec-2000	18.3	S	23.7	G	1,126	1,458	332	23%
Jan-2001	24.0	S	27.9	G	1,475	1,718	243	14%
Feb-2001	56.6	S	56.0	G	3,142	3,108	(34)	-1%
Mar-2001	56.1	S	56.8	G	3,451	3,491	40	1%
Apr-2001	36.7	S	35.8	G	2,184	2,130	(54)	-3%
May-2001	42.5	S	39.9	G	2,611	2,454	(157)	-6%
Jun-2001	51.7	S	52.6	G	3,077	3,128	51	2%
Jul-2001	58.0	S	57.9	G	3,567	3,560	(7)	0%
Aug-2001	54.8	S	55.9	G	3,372	3,435	63	2%
Sep-2001	18.3	S	22.0	G	1,088	1,307	219	17%

	Average cfs	Average cfs	Total acre-feet	Total acre-feet		
WY 1997	52.3	52.0	37,786	37,550	(237)	-1%
WY 1998	60.6	63.9	43,550	45,939	2,389	5%
WY 1999	42.1	44.7	30,470	32,310	1,840	6%
WY 2000	40.5	43.1	29,350	31,260	1,910	6%
WY 2001	37.4	39.1	27,005	28,234	1,229	4%

(Column 15). These differences are within the margin of error for flow measurements specified in the Quality Assurance Project Plan. The remaining months (October 2000 – January 2001, September 2001) show significant gains of water (14 – 23 percent). This is most likely seepage into the drain from adjacent wetland ponds.

Salt Mass Balance between Stations A and B

Figure 2 shows the monthly loads of salt in water that passed Stations A and B during WY 2001. Figure 2b shows the monthly loads of salt in water that passed Stations A and B during the five years of the Project.

Table 2 compares monthly loads of salts in water that passed Stations A and B during the five years of the Project. There was a net difference of about 5,400 tons of salt betwen Stations A and B during this water year. Figure 2 shows the monthly loads of salts that passed these stations during the five years of the Project.

Since salinity is a conservative chemical constituent, the monthly salt load measured at Station A should be identical to that at Station B. An increase in salt load must infer inflow of saline water into the SLD from adjacent wetlands if other factors such as precipitation and evaporation are taken into account. A decrease in salt load would infer the loss of saline water from the drain.

The WY 2001 monthly differences in salt loads, ±15 percent, are probably the result of cumulative errors from different analytical methods and equipment. Flow at Station A is measured as flow over a sharp-crested weir with a precision of ±5 percent. The USGS has developed a stage-discharge rating curve for Station B; the accuracy of flow measurements with this method is between – 4 % and +6 percent. The net difference in flow between the stations was about 4 percent (27,000 vs. 28,200 acre-feet).

Drift in the EC sensor response can also affect the computation of salt load. However, EC is measured with identical sensors and methods at both sites. USGS staff consider the EC sensor at Station B to be accurate within 3 percent. In previous years, algae bio-fouling of the probe at Station B has caused errors of more than 30 percent during summer months, but diligent maintenance prevented this from occurring and kept the rate of error less than 10 percent. The difference in flow-weighted average EC between the stations was about 11 percent (4,490 vs. 4,380 μS/cm).

Figure 2. Comparison of Salt Loads in the San Luis Drain WY 1997 - 2001

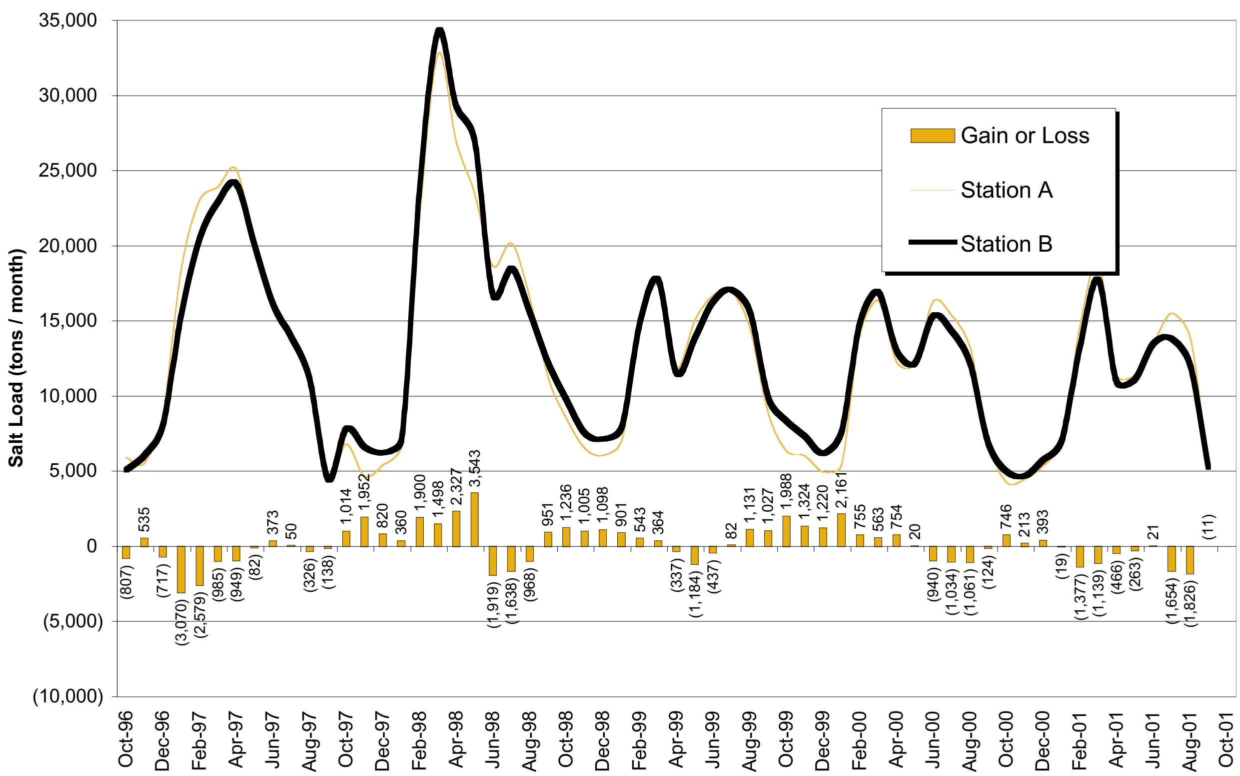

Table 2. Comparison of Salinity and Salt Loads

	Flow-weighted Electrical Conductivity				Loads			
	Station A µS/cm		Station B µS/cm		Station A tons/month	Station B tons/month	difference	Percent of Station B
Oct-1996	4,326	Rr	3,948	L	5,877	5,070	(807)	-16%
Nov-1996	3,812	Rr	3,830	L	5,513	6,048	535	9%
Dec-1996	4,775	Rr	4,095	L	8,737	8,020	(717)	-9%
Jan-1997	4,804	Rr	4,142	L	18,503	15,433	(3,070)	-20%
Feb-1997	5,256	Rr	4,872	L	23,042	20,463	(2,579)	-13%
Mar-1997	4,628	Rr	4,669	L	23,898	22,913	(985)	-4%
Apr-1997	5,391	Rr	5,380	L	25,060	24,111	(949)	-4%
May-1997	4,654	Rr	4,730	L	20,145	20,063	(82)	0%
Jun-1997	4,823	Rr	4,642	L	15,780	16,153	373	2%
Jul-1997	4,217	Rr	4,206	L	13,823	13,873	50	0%
Aug-1997	3,722	Rr	3,497	L	11,443	11,117	(326)	-3%
Sep-1997	3,311	Rr	3,077	L	4,612	4,474	(138)	-3%
Oct-1997	5,065	Rr	4,425	L	6,805	7,819	1,014	13%
Nov-1997	4,640	Rr	4,206	L	4,642	6,594	1,952	30%
Dec-1997	5,016	Rr	4,398	L	5,401	6,221	820	13%
Jan-1998	5,393	Rr	4,919	L	6,676	7,036	360	5%
Feb-1998	3,200	Rr	3,397	L	22,006	23,906	1,900	8%
Mar-1998	4,599	Rr	4,788	L	32,746	34,244	1,498	4%
Apr-1998	4,914	Rr	5,258	L	26,923	29,250	2,327	8%
May-1998	4,952	Rr	5,494	L	23,493	27,036	3,543	13%
Jun-1998	5,109	Rr	4,576	L	18,659	16,740	(1,919)	-11%
Jul-1998	4,408	Rr	4,020	L	20,132	18,494	(1,638)	-9%
Aug-1998	4,267	Rr	3,983	L	16,529	15,561	(968)	-6%
Sep-1998	3,938	Rr	3,798	L	11,252	12,203	951	8%
Oct-1998	4,972	Gr	4,738	Gr	8,506	9,742	1,236	13%
Nov-1998	5,371	Gr	4,909	Gr	6,541	7,546	1,005	13%
Dec-1998	5,268	Gr	4,881	Gr	6,044	7,142	1,098	15%
Jan-1999	5,010	Gr	4,628	Gr	7,008	7,909	901	11%
Feb-1999	4,687	Gr	4,467	Gr	14,340	14,883	543	4%
Mar-1999	5,363	Gr	5,117	Gr	17,379	17,743	364	2%
Apr-1999	5,511	Gr	5,512	Gr	11,869	11,532	(337)	-3%
May-1999	4,973	Gr	4,637	Gr	15,014	13,830	(1,184)	-9%
Jun-1999	4,581	Gr	4,471	Gr	16,689	16,252	(437)	-3%
Jul-1999	4,230	Gr	4,380	Gr	16,986	17,068	82	0%
Aug-1999	3,648	Gr	3,960	Gr	14,465	15,596	1,131	7%
Sep-1999	4,234	Gr	4,094	Gr	8,863	9,890	1,027	10%
Oct-1999	5,423	Rr	4,482	Gr	6,341	8,329	1,988	24%
Nov-1999	4,693	Rr	4,253	Gr	6,010	7,334	1,324	18%
Dec-1999	4,853	Rr	4,383	Gr	4,957	6,177	1,220	20%
Jan-2000	4,158	Rr	4,355	Gr	5,359	7,520	2,161	29%
Feb-2000	4,554	S	4,622	Gr	14,089	14,844	755	5%
Mar-2000	5,051	S	5,047	Gr	16,353	16,916	563	3%
Apr-2000	4,669	S	4,863	Gr	12,283	13,037	754	6%
May-2000	4,150	S	4,238	Gr	12,137	12,157	20	0%
Jun-2000	4,269	S	4,190	Gr	16,253	15,313	(940)	-6%
Jul-2000	4,017	S	3,899	Gr	15,378	14,344	(1,034)	-7%
Aug-2000	3,669	S	3,485	Gr	13,241	12,180	(1,061)	-9%
Sep-2000	4,230	S	3,792	Gr	6,967	6,843	(124)	-2%
Oct-2000	4,340	S	3,919	Gr	4,245	4,991	746	15%
Nov-2000	4,733	S	3,949	Gr	4,477	4,690	213	5%
Dec-2000	4,713	S	3,908	Gr	5,341	5,734	393	7%
Jan-2001	4,692	S	4,018	Gr	6,965	6,946	(19)	0%
Feb-2001	4,635	S	4,245	Gr	14,656	13,279	(1,377)	-10%
Mar-2001	5,438	S	5,052	Gr	18,887	17,748	(1,139)	-6%
Apr-2001	5,183	S	5,096	Gr	11,392	10,926	(466)	-4%
May-2001	4,318	S	4,488	Gr	11,346	11,083	(263)	-2%
Jun-2001	4,340	S	4,276	Gr	13,440	13,461	21	0%
Jul-2001	4,314	S	3,860	Gr	15,487	13,833	(1,654)	-12%
Aug-2001	4,096	S	3,492	Gr	13,900	12,074	(1,826)	-15%
Sep-2001	4,801	S	3,988	Gr	5,257	5,246	(11)	0%

	Average µS/cm	Average µS/cm	Total tons	Total tons	difference	
WY 1997	4,477	4,257	176,433	167,739	(8,695)	-5%
WY 1998	4,625	4,439	195,263	205,104	9,841	5%
WY 1999	4,821	4,650	143,705	149,133	5,428	4%
WY 2000	4,478	4,301	129,368	134,994	5,626	4%
WY 2001	4,634	4,191	125,394	120,011	(5,383)	-4%

Selenium Mass Balance between Stations A and B

A simple mass balance of selenium was calculated to better understand the dynamics of selenium mass transport and mass transfer within the San Luis Drain. Selenium is a non-conservative chemical constituent. These data are presented in Table 3. Despite the seepage inflow, there is little difference (three percent) in the loads of selenium that passed each station. About 116 pounds of selenium that entered the drain at Station A did not flow past Station B, a reduction of about 3 percent.

Flow data, when combined with continuous and discrete selenium data, are used to compute this mass balance. However, selenium sampling does not occur at the same frequency at both Stations A and B.

During WY 2001, selenium samples were collected by auto-samplers at both sites. At Station B, seven samples were collected each day; the composite of each day's samples were analyzed in the laboratory. At Station A, seven daily samples were mixed to produce a single weekly composite for analysis. In addition, CVRWQCB collected weekly grab samples at both sites.

Figure 3 shows the monthly loads of selenium at both sites during the five years of the GBP. Table 3 lists the monthly loads of selenium in water passing both stations.

During WY 2001, there was a slight reduction in the load of selenium that flowed between Stations A and B. The load decreased during eight months.

The reduction of selenium between the sites may be due to measurement error, microbial uptake, adsorption to sediments, volatilization, or seepage from the SLD between the sites. The increase of selenium may be due to measurement error or seepage of seleniferous water into the drain between Stations A and B.

Conclusions

In the five years of the GBP, there have been slight increases in the volume of water in the San Luis Drain during autumn and winter months when adjacent wetlands are flooded. The annual loads of salts have varied ± 5 percent. A annual loads of selenium have varied from a net loss of 7 percent to a gain of 6 percent. These differences are within the realm of measurement error. The differences in selenium loads due to natural processes cannot be determined.

Figure 3. Comparison of Selenium Loads in the San Luis Drain WY 1997 - 2001

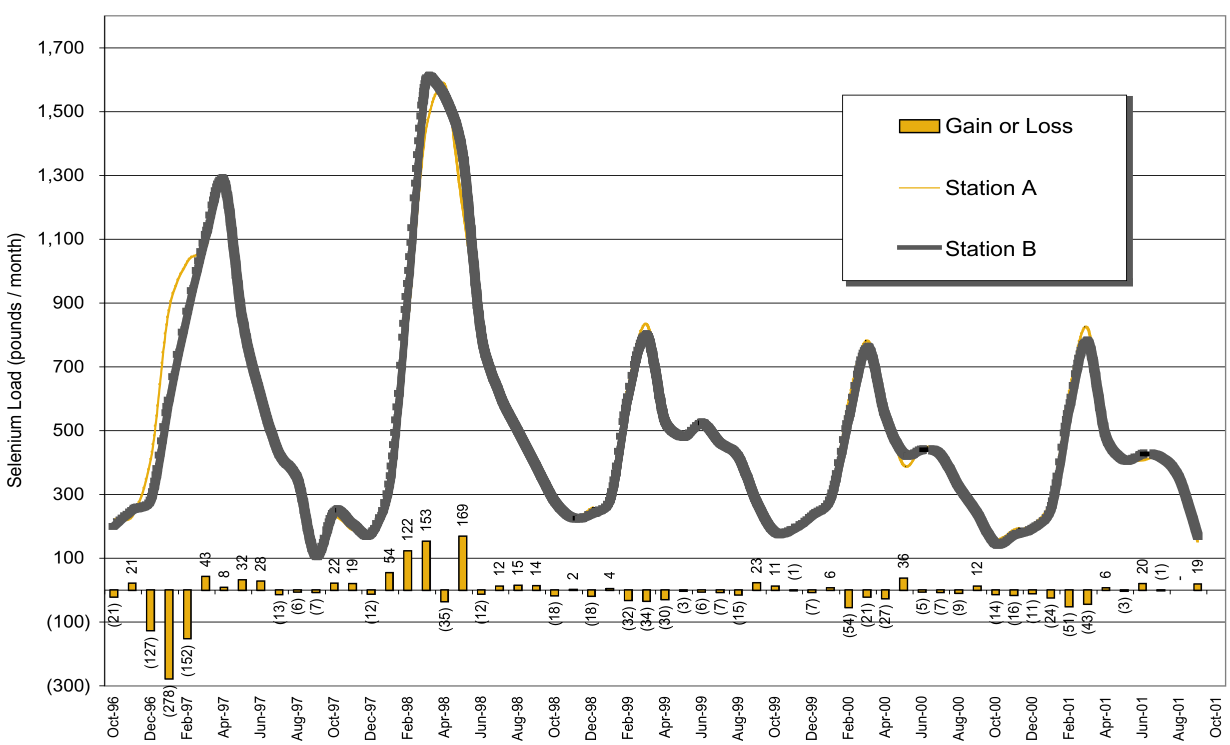

Table 3. Comparison of Selenium Measurements

	Flow-weighted Concentration		Loads			
	Station A µg/L	Station B µg/L	Station A lbs/month	Station B lbs/month	Difference	Percent of Station B
Oct-1996	60.6	58.3	223	202	(21)	-10%
Nov-1996	59.2	59.0	232	252	21	8%
Dec-1996	83.2	53.9	412	285	(127)	-44%
Jan-1997	84.3	59.5	877	599	(278)	-46%
Feb-1997	86.9	77.3	1,030	878	(152)	-17%
Mar-1997	77.1	84.4	1,076	1,119	43	4%
Apr-1997	101.2	105.7	1,272	1,280	8	1%
May-1997	69.8	74.1	817	849	32	4%
Jun-1997	65.9	65.0	583	611	28	5%
Jul-1997	49.8	48.0	441	428	(13)	-3%
Aug-1997	42.6	40.5	354	348	(6)	-2%
Sep-1997	30.7	27.7	116	109	(7)	-6%
Oct-1997	62.3	51.9	226	248	22	9%
Nov-1997	69.4	48.9	188	207	19	9%
Dec-1997	65.4	46.6	190	178	(12)	-7%
Jan-1998	84.2	86.7	282	335	54	16%
Feb-1998	45.3	50.8	843	965	122	13%
Mar-1998	75.2	82.8	1,447	1,600	153	10%
Apr-1998	107.1	103.1	1,585	1,550	(35)	-2%
May-1998	93.7	103.0	1,201	1,370	169	12%
Jun-1998	83.0	81.6	819	807	(12)	-2%
Jul-1998	48.8	49.5	603	615	12	2%
Aug-1998	46.3	47.4	485	500	15	3%
Sep-1998	48.5	44.7	374	388	14	4%
Oct-1998	63.7	49.5	295	277	(18)	-6%
Nov-1998	67.9	53.2	224	226	2	1%
Dec-1998	82.6	61.0	257	239	(18)	-7%
Jan-1999	73.9	62.1	280	284	4	1%
Feb-1999	77.5	67.0	641	609	(32)	-5%
Mar-1999	95.3	85.9	833	799	(34)	-4%
Apr-1999	96.1	90.2	559	529	(30)	-6%
May-1999	59.5	60.3	485	482	(3)	-1%
Jun-1999	53.7	53.3	530	524	(6)	-1%
Jul-1999	43.2	43.8	469	462	(7)	-1%
Aug-1999	40.4	39.1	433	418	(15)	-4%
Sep-1999	44.6	41.8	252	275	23	8%
Oct-1999	53.7	35.1	170	181	11	6%
Nov-1999	56.1	41.4	194	193	(1)	-1%
Dec-1999	88.1	61.9	243	236	(7)	-3%
Jan-2000	80.0	61.0	279	285	6	2%
Feb-2000	101.0	62.3	595	541	(54)	-10%
Mar-2000	96.8	84.0	782	761	(21)	-3%
Apr-2000	92.9	75.8	576	549	(27)	-5%
May-2000	49.4	55.1	391	427	36	9%
Jun-2000	43.2	44.4	444	439	(5)	-1%
Jul-2000	41.8	42.7	432	425	(7)	-2%
Aug-2000	34.1	34.3	333	324	(9)	-3%
Sep-2000	51.6	49.7	230	242	12	5%
Oct-2000	61.2	42.8	160	146	(14)	-9%
Nov-2000	74.9	54.4	190	174	(16)	-9%
Dec-2000	66.8	48.9	205	194	(11)	-5%
Jan-2001	69.5	53.8	279	255	(24)	-9%
Feb-2001	72.6	67.2	625	574	(51)	-9%
Mar-2001	87.0	82.0	822	779	(43)	-6%
Apr-2001	79.9	82.9	475	481	6	1%
May-2001	58.8	62.5	411	408	(3)	-1%
Jun-2001	48.5	49.9	406	426	20	5%
Jul-2001	43.0	42.9	417	416	(1)	0%
Aug-2001	38.7	37.9	353	353	0	0%
Sep-2001	50.0	47.2	152	171	19	11%

	average µg/L	average µg/L	total pounds	total pounds	difference	
WY 1997	67.6	62.8	7,431	6,960	(471)	-6%
WY 1998	69.1	66.4	8,244	8,763	519	6%
WY 1999	66.5	58.9	5,257	5,124	(133)	-3%
WY 2000	65.7	54.0	4,669	4,603	(65)	-1%
WY 2001	62.6	56.0	4,493	4,377	(116)	-3%

Table 4. Grassland Bypass Project San Luis Drain Discharge Balance

	CIMIS ETo				Evaporation (Kc=1.1)		Water Loss to Evap.	Water Gain from Precip	Gain or Loss from Water Surface	Site A	Site B	B-A	Net Water Gain/Loss	Equivalent Flowrate	Percent of Discharge
	Panoche	Telles	Los Banos	Average	inches	feet	acre feet	acre feet	acre feet	acre feet	acre feet	acre feet	acre feet	cfs	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Oct-1999	4.26	4.28	3.76	4.10	4.51	0.38	38.3	0.0	-38.3	1,162	1,850	688	726.3	11.8	39%
Nov-1999	2.02	1.97	1.63	1.87	2.06	0.17	17.5	2.1	-15.4	1,273	1,710	437	452.4	7.4	26%
Dec-1999	1.78	1.81	1.42	1.67	1.84	0.15	15.6	0.5	-15.1	1,015	1,400	385	400.1	6.5	29%
Jan-2000	1.12	1.12	0.86	1.03	1.14	0.09	9.6	13.0	3.4	1,281	1,720	439	435.6	7.1	25%
Feb-2000	1.48	1.54	1.36	1.46	1.61	0.13	13.6	17.3	3.7	3,074	3,190	116	112.3	1.8	4%
Mar-2000	4.04	4.15	3.90	4.03	4.43	0.37	37.6	3.5	-34.1	3,217	3,330	113	147.1	2.4	4%
Apr-2000	5.46	5.66	5.25	5.46	6.00	0.50	50.9	9.6	-41.3	2,614	2,660	46	87.3	1.4	3%
May-2000	7.74	7.60	6.87	7.40	8.14	0.68	69.1	0.8	-68.3	2,906	2,850	-56	12.3	0.2	0%
Jun-2000	8.57	8.50	8.34	8.47	9.32	0.78	79.0	0.8	-78.2	3,783	3,630	-153	-74.8	-1.2	-2%
Jul-2000	8.04	8.28	8.34	8.22	9.04	0.75	76.7	0.0	-76.7	3,804	3,660	-144	-67.3	-1.1	-2%
Aug-2000	7.20	7.37	7.40	7.32	8.06	0.67	68.3	0.2	-68.1	3,586	3,470	-116	-47.9	-0.8	-1%
Sep-2000	5.22	5.41	5.25	5.29	5.82	0.49	49.4	0.3	-49.1	1,637	1,790	153	202.1	3.3	11%
Oct-2000	3.56	3.49	3.42	3.49	3.84	0.32	32.6	12.9	-19.7	972	1,270	298	317.7	5.2	25%
Nov-2000	1.88	1.79	1.70	1.79	1.97	0.16	16.7	0.9	-15.8	940	1,180	240	255.8	4.3	22%
Dec-2000	1.28	1.23	1.25	1.25	1.38	0.11	11.7	0.7	-11.0	1,126	1,460	334	345.0	5.6	24%
Jan-2001	1.56	1.54	1.48	1.53	1.68	0.14	14.2	15.7	1.5	1,475	1,720	245	243.5	4.0	14%
Feb-2001	2.08	2.05	1.99	2.04	2.24	0.19	19.0	12.0	-7.0	3,142	3,110	-32	-25.0	-0.4	-1%
Mar-2001	4.22	4.15	3.95	4.11	4.52	0.38	38.3	10.7	-27.6	3,451	3,490	39	66.6	1.1	2%
Apr-2001	5.76	5.25	5.15	5.39	5.93	0.49	50.3	7.7	-42.6	2,184	2,130	-54	-11.4	-0.2	-1%
May-2001	9.80	9.22	8.44	9.15	10.07	0.84	85.4	1.1	-84.3	2,611	2,454	-157	-72.7	-1.2	-3%
Jun-2001	9.58	9.24	8.84	9.22	10.14	0.85	86.0	0.2	-85.8	3,077	3,130	53	138.8	2.3	4%
Jul-2001	8.11	8.04	8.00	8.05	8.86	0.74	75.1	0.0	-75.1	3,567	3,560	-7	68.1	1.1	2%
Aug-2001	7.68	7.89	7.77	7.78	8.56	0.71	72.6	0.0	-72.6	3,372	3,440	68	140.6	2.3	4%
Sep-2001	5.80	5.92	5.78	5.83	6.42	0.53	54.4	0.5	-53.9	1,088	1,310	222	275.9	4.6	21%

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Notes:

(1) - (3)	CIMIS base evapotranspiration in inches
(4)	Average of (1) through (3)
(5) & (6)	Evaporation calculated from ETo. Kc value based on UC Extension leaflet 21427
(7)	(6) x SLD surface area. SLD surface area = 28 mi x 30' top width = 101.8 ac
(8)	Monthly CIMIS precipitation (Tellis, Panoche, and Los Banos) applied to SLD surface area
(9)	(8) - (7)
(10)	Site A discharge in acre feet
(11)	Site B discharge in acre feet
(12)	(11) - (10)
(13)	Net water volume gained from or lost to local high ground water = (12) - (9)
(14)	Average daily flowrate (cfs) of the Net Water Gain
(15)	(14) / (11) x 100%

GRASSLAND BYPASS PROJECT

6

Project Impacts on the San Joaquin River

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Introduction

The purpose of this chapter is to compare the loads of salt discharged by the Grassland Bypass Project (GBP) with loads that might exist in the absence of the Project. This comparison uses flow and salinity data for Stations B, D, F, and N from October 1985 to September 2001. Two methods are used:

1. simple comparison of flow and salt loads as percentages, and
2. a theoretical dilution analysis.

The theoretical dilution analysis was agreed upon in meetings involving the US Bureau of Reclamation, the South Delta Water Agency and its legal counsel, and the California Regional Water Quality Control Board, as a means of demonstrating that the Project was not causing adverse downstream impacts. This analysis was not specified in the Compliance Monitoring Program (USBR, 1996) or the Quality Assurance Project Plan (Entrix, 1997). Work continues to standardize the methodologies used to calculate loads and the theoretical dilution.

The 1995 Agreement for Use of the San Luis Drain includes the following statement:

> "It is the objective and intention of RECLAMATION and the AUTHORITY, among other things, to ensure that the use of the Drain as provided in this Agreement does not result in degradation of water quality in the San Joaquin River relative to the quality that would exist in the absence of the project and does not reduce the ability to meet the salinity standard at Vernalis compared to the ability to meet the salinity standard that would exist in the absence of the project." (USBR, et. al., 1995)

Comparison of Flow and Salt Loads as Percentages

Table 1 compares the monthly flows and loads of salt discharged by the GBP with those in the San Joaquin River at Crows Landing. During WY 2001, discharge from the GBP was 4 percent of the flow and about 19 percent of the salt load in the river as measured at Crows Landing.

Tables 2a, 2b, and 2c compare the volumes of water discharged from the 97,000 acre Grassland Drainage Area (GDA) with flow in the Mud and Salt Slough watershed. During the WY 2001, 28,300 acre-feet of water were discharged from the GDA, which was approximately 12 percent of the 226,800 acre-feet that flowed from the region. The WY 2001 volume was about 39 percent less than the average annual volume of drainage water discharged prior to the GBP (28,300 acre-feet vs. 49,800 acre-feet).

Tables 3a, 3b, and 3c compare the loads of salts discharged from the GDA with the salts in Mud and Salt Sloughs. During the WY 2001, about 120,000 tons of salt were discharged from the GDA, which was almost 31 percent of the 383,200 tons left the region in Mud and Salt Sloughs. The WY 2001 salt load was about 37 percent less than the average annual salt load discharged prior to the GBP (120,000 tons vs. 190,500 tons) between WY 1986 and WY 1996. The WY 2001 regional salt load was about the same as the average annual salt load discharged prior to the GBP (383,200 tons versus 388,300 tons).

Theoretical Dilution of GBP Discharges to Meet Vernalis Standards

In order to assess the effect of GBP on salinity in the San Joaquin River, an analysis was developed to theoretically isolate the effects of GBP from other activities potentially affecting salinity concentrations in the river. Drainage from GBP was assumed as the only drainage relevant to project related changes in salt load on the San Joaquin River. The analysis was cast in terms of theoretical dilution water needed to bring the GBP discharges to the Vernalis seasonal EC objectives.

The salinity objectives for Vernalis are 1,000 µS/cm (640 mg/L) in the winter months (September–March) and 700 µS/cm (448 mg/L) in the summer months (April–August)(CVRWQCB 1998).

This analysis does not take into account any of the other operational criteria, nor does it consider salinity contributions to the River other than those derived from the GDA. The value of the analysis is that it permits a "with" and "without" project comparison with prior year hydrology, in terms (water quality releases from a reservoir) meaningful to water users and managers.

The assimilative capacity analysis considers the total volume of dilution water (assumed to have a salinity of 156 µS/cm (100 mg/L)) that would be needed to reduce the drainage water alone to the salinity objective.

Table 1. Comparison of Flows and Salt Loads Discharged by the Grassland Bypass Project to the San Joaquin River (WY 1997 - 2001)

	Flow			Salt Load		
	Discharged from GDA	San Joaquin River at Crows Landing		Discharged from GDA	San Joaquin River at Crows Landing	
	Station B	Station N	B as %	Station B	Station N	B as %
	acre-feet	acre-feet	of N	tons	tons	of N
Monthly Totals						
Oct-1996	1,276	62,290	2%	5,070	33,262	15%
Nov-1996	1,569	61,120	3%	6,048	44,792	14%
Dec-1996	1,946	268,300	1%	8,020	73,753	11%
Jan-1997	3,703	1,574,000	0%	15,433	220,954	7%
Feb-1997	4,173	1,299,000	0%	20,463	253,517	8%
Mar-1997	4,876	283,700	2%	22,913	178,110	13%
Apr-1997	4,453	80,480	6%	24,111	73,128	33%
May-1997	4,215	76,100	6%	20,063	58,784	34%
Jun-1997	3,457	35,980	10%	16,153	42,186	38%
Jul-1997	3,277	35,850	9%	13,873	35,876	39%
Aug-1997	3,159	37,630	8%	11,117	41,729	27%
Sep-1997	1,445	29,820	5%	4,474	24,611	18%
Oct-1997	1,756	39,860	4%	7,819	34,861	22%
Nov-1997	1,558	44,690	3%	6,594	49,011	13%
Dec-1997	1,406	53,260	3%	6,221	60,705	10%
Jan-1998	1,421	139,600	1%	7,036	80,603	9%
Feb-1998	6,993	1,001,000	1%	23,906	360,319	7%
Mar-1998	7,106	623,100	1%	34,244	266,927	13%
Apr-1998	5,527	832,100	1%	29,250	238,007	12%
May-1998	4,890	743,600	1%	27,036	152,762	18%
Jun-1998	3,635	707,300	1%	16,740	109,320	15%
Jul-1998	4,572	502,700	1%	18,494	69,341	27%
Aug-1998	3,883	108,100	4%	15,561	47,242	33%
Sep-1998	3,193	109,600	3%	12,203	42,371	29%
Oct-1998	2,040	128,600	2%	9,742	44,509	22%
Nov-1998	1,530	73,090	2%	7,546	52,300	14%
Dec-1998	1,450	95,490	2%	7,142	52,295	14%
Jan-1999	1,700	96,020	2%	7,909	64,734	12%
Feb-1999	3,310	161,500	2%	14,883	82,991	18%
Mar-1999	3,450	113,600	3%	17,743	101,750	17%
Apr-1999	2,080	115,200	2%	11,532	72,955	16%
May-1999	2,960	84,070	4%	13,830	54,820	25%
Jun-1999	3,610	40,690	9%	16,252	44,925	36%
Jul-1999	3,870	34,840	11%	17,068	37,983	45%
Aug-1999	3,910	37,810	10%	15,596	39,320	40%
Sep-1999	2,400	34,440	7%	9,890	31,517	31%
Oct-1999	1,850	51,890	4%	8,329	38,233	22%
Nov-1999	1,710	52,230	3%	7,334	48,036	15%
Dec-1999	1,400	42,230	3%	6,177	47,265	13%
Jan-2000	1,720	59,110	3%	7,520	58,618	13%
Feb-2000	3,190	201,700	2%	14,844	90,098	16%
Mar-2000	3,330	274,900	1%	16,916	136,826	12%
Apr-2000	2,660	100,200	3%	13,039	70,370	19%
May-2000	2,850	84,830	3%	12,157	65,234	19%
Jun-2000	3,630	43,800	8%	15,313	44,821	34%
Jul-2000	3,660	41,610	9%	14,344	40,284	36%
Aug-2000	3,470	38,800	9%	12,180	35,341	34%
Sep-2000	1,790	36,180	5%	6,843	28,751	24%
Oct-2000	1,265	64,622	2%	4,991	34,895	14%
Nov-2000	1,180	62,365	2%	4,690	38,171	12%
Dec-2000	1,458	51,105	3%	5,734	46,135	12%
Jan-2001	1,718	59,338	3%	6,946	61,974	11%
Feb-2001	3,108	60,475	5%	13,279	71,153	19%
Mar-2001	3,491	97,685	4%	17,748	108,025	16%
Apr-2001	2,130	71,848	3%	10,926	63,653	17%
May-2001	2,454	71,229	3%	11,083	70,764	16%
Jun-2001	3,128	31,028	10%	13,461	36,138	37%
Jul-2001	3,560	28,999	12%	13,833	32,218	43%
Aug-2001	3,435	28,999	12%	12,074	32,284	37%
Sep-2001	1,307	22,251	6%	5,246	25,028	21%
Annual Totals						
WY 1997	37,550	3,844,270	1%	167,739	1,080,703	16%
WY 1998	45,939	4,904,910	1%	205,104	1,511,470	14%
WY 1999	32,310	1,015,350	3%	149,133	680,098	22%
WY 2000	31,260	1,027,480	3%	134,994	703,876	19%
WY 2001	28,234	649,944	4%	120,011	620,438	19%

Table 2a. Annual Volume of Water Discharged from the Grassland Drainage Area and Mud/Salt Slough Watershed

Water Year (1)		% CVP Contract Delivery (2)	Discharge from GDA (3)	Discharge from Region (4)	GDA discharge as percent of Regional discharge
			acre-feet	acre-feet	
WY 1986		100%	67,006	284,316	24%
WY 1987		100%	74,902	233,843	32%
WY 1988		100%	65,327	230,454	28%
WY 1989		100%	54,186	211,393	26%
WY 1990		50%	41,662	194,656	21%
WY 1991		25%	29,290	102,162	29%
WY 1992		25%	24,533	85,428	29%
WY 1993		50%	41,197	167,955	25%
WY 1994		35%	38,670	183,546	21%
WY 1995		100%	57,574	263,769	22%
WY 1996		95%	52,978	267,948	20%
WY 1997	GBP	90%	37,550	287,210	13%
WY 1998	GBP	100%	45,939	378,680	12%
WY 1999	GBP	70%	32,310	253,130	13%
WY 2000	GBP	65%	31,260	235,490	13%
WY 2001	GBP	49%	28,254	226,763	12%

Table 2b. Comparison of WY 2001 Discharge Volume to Previous Years

	Water Year	Discharge from GDA (3)	WY 2001 difference	Discharge from Region (4)	WY 2001 difference
		acre-feet		acre-feet	
Average, all years	1986 - 2001	45,165	-37%	225,421	1%
Prior years average	1986 - 2000	46,292	-39%	225,332	1%
Before GBP average	1986 - 1996	49,757	-43%	202,315	12%
GBP average	1997 - 2001	35,063	-19%	276,255	-18%
Drought years	(5)	33,934	-17%	160,085	42%
Wet years	(6)	54,145	-48%	260,520	-13%

Table 2c. Total Volumes of Water

	Water Years	Discharge from GDA (3)	Discharge from Region (4)	GDA discharge as percent of Regional discharge
		acre-feet	acre-feet	
All years	1986 - 2001	722,638	3,606,743	20%
Before GBP	1986 - 1996	547,325	2,225,470	25%
GBP total	1997 - 2001	175,313	1,381,273	13%

Notes:

Data compiled by Nigel Quinn, LBNL, from CVRWQCB and USGS reports.

(1) Water Year - October 1 - September 30

(2) Percent of Contract Delivery of CVP water to Delta Division and San Luis Unit

(3) Grassland Drainage Area

(4) Mud and Salt Sloughs

(5) Drought Years with 50% or less CVP delivery: WY 1990 - 1994, 2001

(6) Wet Years with more than 50 percent CVP delivery: WY 1986 - 1989, 1995 - 2000

Table 3a. Annual Loads of Salt Discharged from the Grassland Drainage Area and Mud/Salt Slough Watershed

Water Year (1)		% CVP Contract Delivery (2)	Discharge from GDA (3)	Discharge from Region (4)	GDA load as percent of Regional load
			tons	tons	
WY 1986		100%	214,250	494,544	43%
WY 1987		100%	241,526	438,904	55%
WY 1988		100%	236,301	455,956	52%
WY 1989		100%	202,420	389,325	52%
WY 1990		50%	171,265	380,564	45%
WY 1991		25%	129,899	221,542	59%
WY 1992		25%	110,327	197,352	56%
WY 1993		50%	183,021	336,522	54%
WY 1994		35%	171,495	379,408	45%
WY 1995		100%	237,530	499,339	48%
WY 1996		95%	197,526	477,725	41%
WY 1997	GBP	90%	167,739	446,690	38%
WY 1998	GBP	100%	205,104	627,687	33%
WY 1999	GBP	70%	149,133	401,616	37%
WY 2000	GBP	65%	134,994	372,453	36%
WY 2001	GBP	49%	120,008	383,155	31%

Table 3b. Comparison of WY 2001 Salt Loads to Previous Years

		Discharge from GDA (3)	WY 2001 difference	Discharge from Region (4)	WY 2001 difference
		acre-feet		acre-feet	
Average, all years	1986 - 2001	179,534	-33%	406,424	-6%
Prior years average	1986 - 2000	183,502	-35%	407,975	-6%
Before GBP average	1986 - 1996	190,505	-37%	388,289	-1%
GBP average	1997 - 2001	155,396	-23%	446,320	-14%
Drought years (2)	(5)	147,669	-19%	316,424	21%
Wet years	(6)	202,814	-41%	457,800	-16%

Table 3c. Total Salts

		Discharge from GDA (3)	Discharge from Region (4)	GDA load as percent of Regional load
		tons	tons	
All years	1986 - 2001	2,872,538	6,502,782	44%
Before GBP	1986 - 1996	2,095,560	4,271,181	49%
GBP total	1997 - 2001	776,978	2,231,601	35%

Notes:

Data compiled by Nigel Quinn, LBNL, from CVRWQCB and USGS reports.

(1) Water Year - October 1 - September 30

(2) Percent of Contract Delivery of CVP water to Delta Division and San Luis Unit

(3) Grassland Drainage Area

(4) Mud and Salt Sloughs

(5) Drought Years with 50% or less CVP delivery: WY 1990 - 1994, 2001

(6) Wet Years with more than 50 percent CVP delivery: WY 1986 - 1989, 1995 - 2000

Note that the monthly volume of dilution water is highly dependent on the 156 μS/cm (100 mg/L) assumption. Note also that the relation between dilution water quality and required volume is non linear.

Figure 1 shows the theoretical volume of water that would be needed to dilute the combined salt loads from the GDA, measured at Station B, and the regional watershed, drained by Mud Slough and Salt Slough (Stations D & F), to meet the Vernalis standards. Figure 2 shows the total theoretical dilution requirement for each water year. The unshaded areas in Figures 1 and 2 represent the theoretical dilution requirements for salt loads generated by the Mud and Salt Slough watershed which includes the GDA and other agricultural areas, wetlands, and uncontrolled runoff from the Coast Range watersheds. The shaded area in the Figures shows the theoretical dilution requirements for salt loads discharged from only the GDA.

The data for Figure 2 are summarized in Tables 4a and 4b. During the WY 2001, about 174,500 acre-feet of water would have been needed to dilute the 28,300 acre-feet of drainage water discharged from the GDA. In comparison, approximately 458,800 acre-feet of water would have been needed to dilute the regional discharges of 226,800 acre-feet to meet the Vernalis standards. The WY 2001 theoretical dilution requirement for the GDA is about 36 percent less than that required during the years prior to the implementation of the GBP. The WY 2001 theoretical dilution requirement for the region was 28 percent higher than that required during the years prior to implementation of the GBP.

These percentages should be put into context of the 1990 – 1994 drought and the initiation of CVPIA deliveries to wetlands (private, State and Federal) in the Grasslands Basin that preceded the authorization of the Grassland Bypass Project. The latter has profoundly affected the hydrology of the Grasslands Basin and has affected the timing of salt loading to the San Joaquin River.

Drought occurred during WY 1990 to 1994 and WY 2001 when 50 percent or less of the contracted supplies of water were delivered to federal contractors in the San Luis Unit and Delta Division of the CVP. The volume of water discharged from the GBP in WY 2001 was comparable to that discharged during the 1990–1994 drought.

Data for the GDA for WY 1986 to 2001 show that between WY 1999 and WY 2001, the salt loads (Tables 3a and 3b) and theoretical dilution requirements (Tables 4a and 4b, and Figures 1 and 2) were smaller than in all other years with the exception of the drought years of WY 1991 and 1992.

The theoretical dilution required for the entire region in WY 2001 was 28 percent larger than the average of all prior years and greater than the average of above normal and wet years with CVP deliveries above 50 percent (Table 4b).

WY 1999, 2000, and 2001 had no unusual or unexpected hydrologic events as occurred in WY 1997 and WY 1998.

Data for several more years will be necessary before the impact of the GBP can be quantified with confidence.

Calculations

The formula for theoretical dilution is:

$Q_2 = Q_1(C_3-C_1)/(C_2-C_3)$

Q_1 = Drainwater discharge in acre-feet per month

Q_2 = Volume of water needed to dilute Q_1 to meet Vernalis standards in acre-feet per month

C_1 = Measured concentration of GBP drainage water in parts per million (mg/L)

C_2 = Assumed concentration of dilution water = 100 mg/L

C_3 = Vernalis standard concentration = 448 mg/L April - August 640 mg/L September - March

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Figure 1. Monthly Volumes of Water Needed to Dilute Drainage Water from the Grassland Drainage Area and Regional Watershed to Meet Vernalis Standards (WY 1986 - 2001)

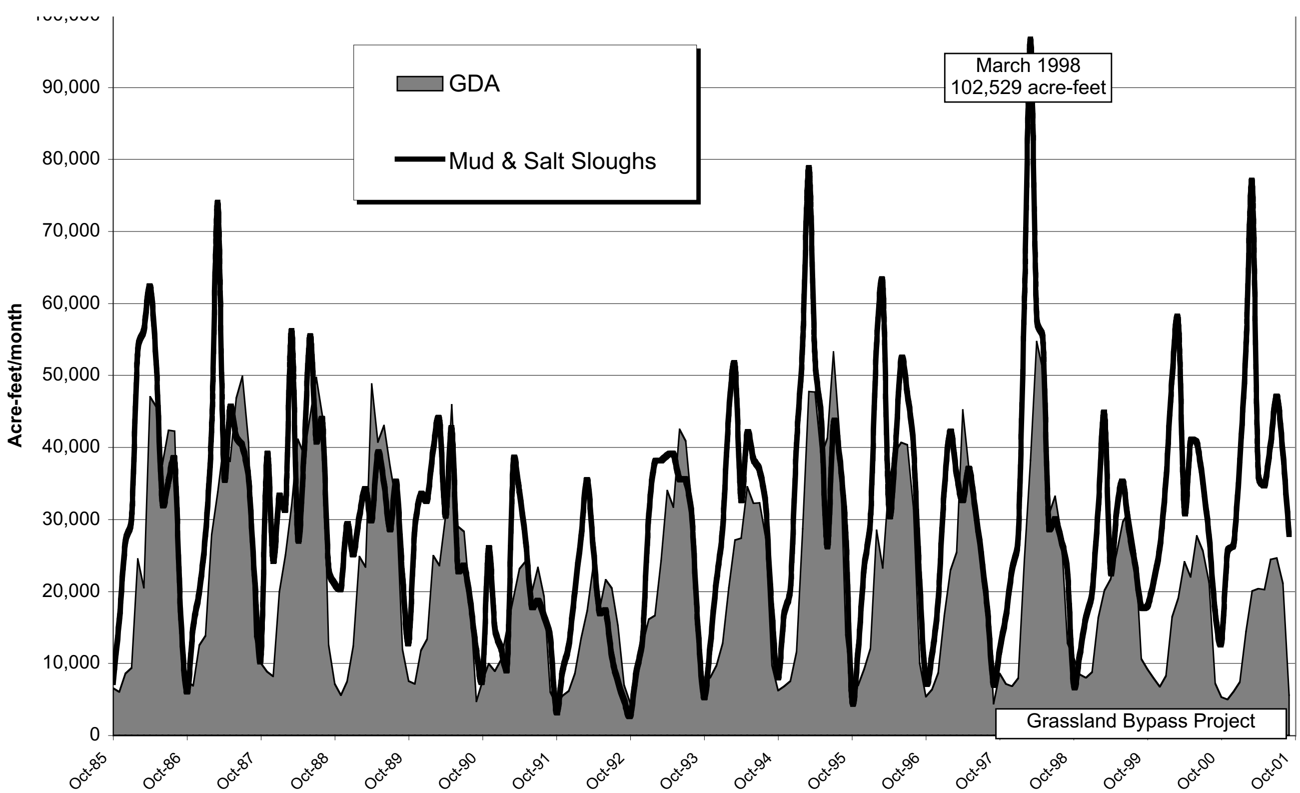
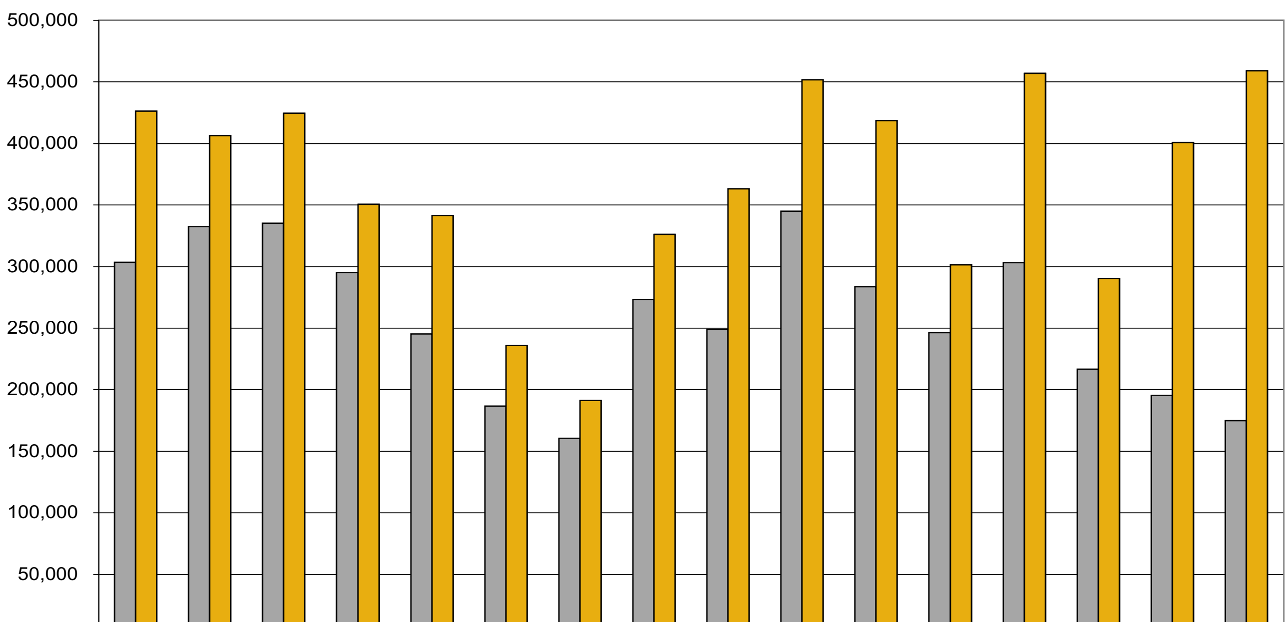


Figure 2. Annual Volumes of Water Needed to Dilute Drainage from the Grassland Drainage Area and the Regional Watershed to Meet Vernalis Standards (WY 1986 - 2001)



	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
GDA	303,361	332,189	335,151	294,834	245,167	186,454	160,419	272,851	249,057	344,983	283,339	246,094	302,996	216,577	195,422	174,543
Regional	426,147	406,134	424,453	350,406	341,299	235,849	191,068	325,964	363,094	451,505	418,393	301,219	456,678	290,092	400,730	458,769

Table 4a. Annual Volumes of Dilution Water Needed to Meet Vernalis Standards

Water Year (1)		Water Needed to Dilute GDA Discharge to Meet Vernalis Standard (3)	Water Needed to Dilute Regional Discharge to Meet Vernalis Standard (4)	GDA as percent of Region
		acre-feet	acre-feet	
WY 1986		303,361	426,147	71%
WY 1987		332,189	406,134	82%
WY 1988		335,151	424,453	79%
WY 1989		294,834	350,406	84%
WY 1990		245,167	341,299	72%
WY 1991		186,454	235,849	79%
WY 1992		160,419	191,068	84%
WY 1993		272,851	325,964	84%
WY 1994		249,057	363,094	69%
WY 1995		344,983	451,505	76%
WY 1996		283,339	418,393	68%
WY 1997	GBP	246,094	301,219	82%
WY 1998	GBP	302,996	456,678	66%
WY 1999	GBP	216,577	290,092	75%
WY 2000	GBP	195,422	400,730	49%
WY 2001	GBP	174,543	458,769	38%

Table 4b. Comparison of Dilution Requirements

		Water Needed to Dilute GDA Discharge to Meet Vernalis Standard (3)	WY 2001 difference	Water Needed to Dilute Regional Discharge to Meet Vernalis Standard (4)	WY 2001 difference
		acre-feet		acre-feet	
Average, all years	1986 - 2001	258,965	-33%	365,112	26%
Prior years average	1986 - 2000	264,593	-34%	358,869	28%
Before GBP average	1986 - 1996	273,437	-36%	357,665	28%
GBP average	1997 - 2001	227,126	-23%	381,498	20%
Drought years	(5)	214,749	-19%	319,341	44%
Wet years	(6)	290,643	-40%	394,110	16%

Notes:

Data compiled by Nigel Quinn, LBNL, from CVRWQCB and USGS reports.

(1) Water Year - October 1 - September 30

(2) Percent of Contract Delivery of CVP water to Delta Division and San Luis Unit

(3) Grassland Drainage Area

(4) Mud and Salt Sloughs

(5) Drought Years with 50% or less CVP delivery: WY 1990 - 1994, 2001

(6) Wet Years with more than 50 percent CVP delivery: WY 1986 - 1989, 1995 - 2000

GRASSLAND BYPASS PROJECT

7 Biological Effects

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Abstract

In the fifth year of operation of the Grassland Bypass Project (GBP), contaminant concentrations in whole-body fish and invertebrates collected at sampling sites in Mud Slough below the outfall of the San Luis Drain (SLD) exceeded thresholds of Concern and Toxicity. The overall hazard of selenium to the ecosystem (Lemly's index) continued to be high in this reach of Mud Slough.

In Salt Slough, where drainwater has been removed by the GBP, average selenium concentrations in fish and invertebrates have remained at No-Effect levels since the latter half of 1998, with the exception of a single logperch (5 mg/kg) collected in June 2001. Lemly's index of selenium hazard to the Salt Slough aquatic ecosystem rose from "low" in WY 2000 to "moderate" in WY 2001 due to a small increase in the maximum concentration of selenium measured in Salt Slough water.

In the San Joaquin River both upstream (Site G) and downstream (Site H) of Mud Slough discharge, selenium concentrations in whole-body fish remain below the Concern threshold of 4 mg/kg (dry weight). Selenium concentrations in all invertebrates collected from the San Joaquin River site upstream of the Mud Slough discharge (Site G) during the fifth year of GBP operation remained below the 3 mg/kg (dry weight) threshold of Concern for invertebrates as prey items. However, the average concentration of selenium in invertebrate samples collected downstream of the Mud Slough discharge (Site H) reached the threshold of Concern for the first time since monitoring began in 1993. The concentrations of selenium in fish muscle tissue collected at both sites remained below the 2 mg/kg (wet weight) limited consumption guideline.

The selenium concentrations in all bird eggs collected in the Salt Slough area were within the No-Effect range. The selenium concentration in a black phoebe egg collected from a nest under a bridge across the SLD exceeded the level of Concern. The Toxicity threshold was exceeded by two killdeer eggs collected along the SLD adjacent to the filled Kesterson Reservoir.

Selenium concentrations in seeds collected at all sites in WY 2001 were below the 3 mg/kg (dry weight) threshold of Concern as diet for birds, with the exception of a sample of swamp timothy seed heads collected at Site D, just below the SLD outfall.

Boron concentrations in seed samples from the banks of Salt Slough were below the threshold of Concern. The boron concentration in samples collected from Mud Slough sites below the SLD outfall were all above the 30 mg/kg (dry weight) threshold of Concern. Two of three seed samples collected along Mud Slough above the outfall (Site C) were above the threshold of Concern.

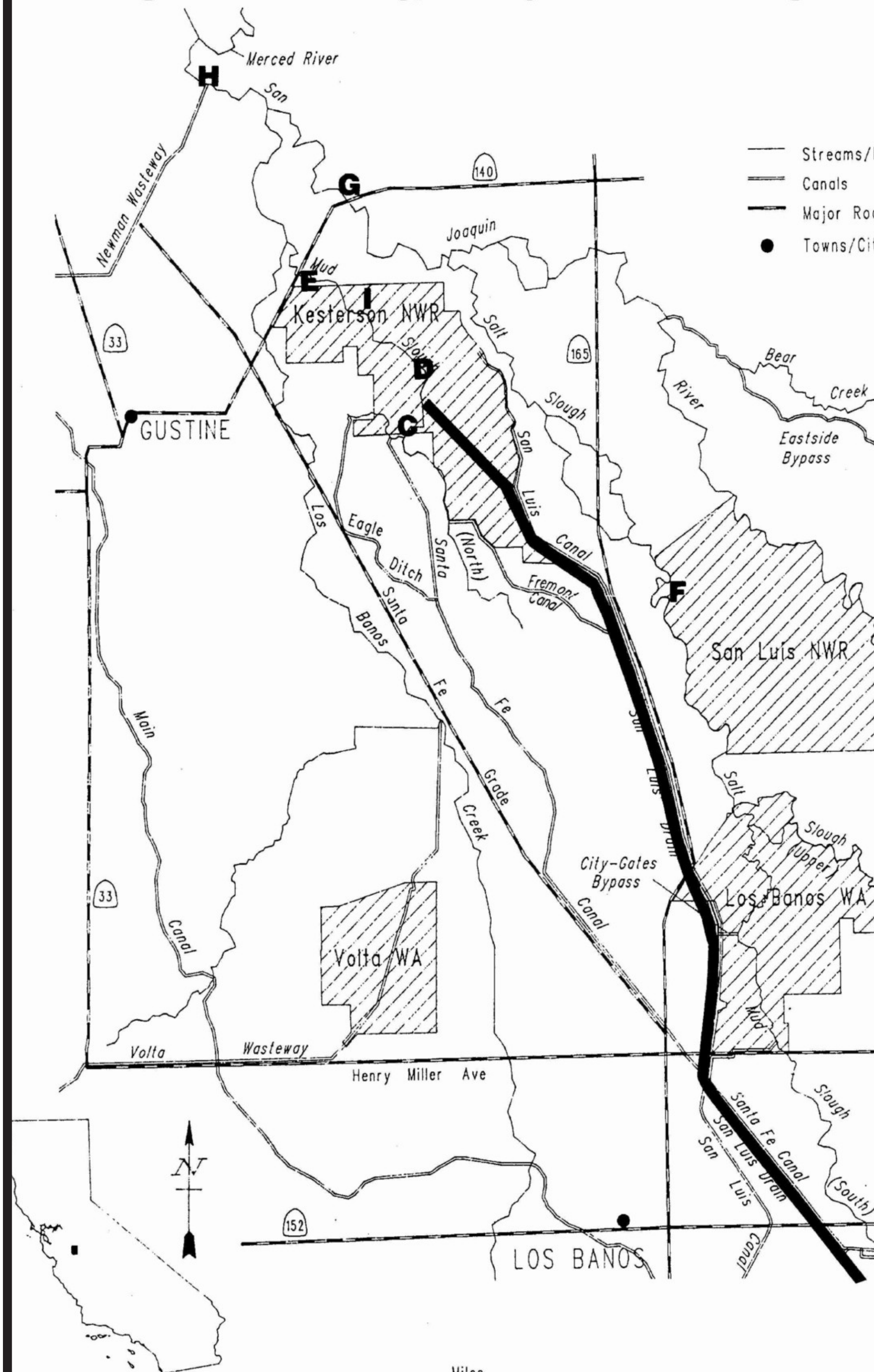
Introduction

Project History

In 1985 the SLD was closed due to deaths and developmental abnormalities of waterbirds at a reservoir in the Kesterson National Wildlife Refuge at the terminus of the SLD. The SLD, constructed by the U.S. Bureau of Reclamation (USBR), had been conceived as a means to dispose of agricultural drainwater generated from irrigation with water supplied by the federal Central Valley Water Project. However, due to environmental concerns and budget constraints, the SLD had never been completed as originally planned. The constructed portion of the SLD had been used only to convey subsurface agricultural drainwater from the Westlands Water District in the western San Joaquin Valley. Farms in the adjacent Grassland Drainage Area (GDA) never used the SLD, but discharged subsurface drainwater through wetland channels in the Grassland Water District, San Luis National Wildlife Refuge Complex, and the China Island Unit of the North Grasslands Wildlife Area (Refuges) to the San Joaquin River. This drainwater contains elevated concentrations of selenium, boron, chromium, and molybdenum, and high concentrations of various salts (CEPA, 2000) that disrupt the normal ionic balance of affected aquatic ecosystems (SJVDP, 1990b). In addition, unknown concentrations of agricultural chemical residues (fertilizers and pesticides that do not readily adsorb to soil) may contaminate this drainwater.

Discharge from GDA farms continued to contaminate Refuge water delivery channels after closure of the SLD and Kesterson Reservoir in 1986. To address this problem, a proposal to use a portion of the SLD and extend it to Mud Slough, a natural waterway in the Refuges, was implemented by the USBR in September 1996 with support from other federal and state agencies (USBR, 1995; USBR and SL&D-MWA 1995; USBR et al., 1995). This project, known as the Grassland Bypass Project (GBP), diverts agricultural drainwater from the GDA into the lower 28 miles of the SLD and thence into the lower portion of Mud Slough (about six miles). The GBP has removed drainwater from more than 90 miles of wetland water supply channels, including Salt Slough, and allows the Refuges full use of water to create and restore wetlands on the Refuges. The GBP, as currently implemented, continues to adversely affect the northernmost six

Figure 1 Grassland Bypass Project biota monitoring sites



miles of Mud Slough and the reach of the San Joaquin River between Mud Slough and the Merced River. However, as phased-in load reduction goals are achieved by GDA farmers, these adverse effects are expected to be reduced. An essential component of the GBP is a monitoring program that tracks contaminant levels and effects in water, sediment, and biota to ensure that the overall effect of the GBP is not a net deterioration of the ecosystems in the area.

Contaminants of Concern

In the aftermath of the deaths and developmental abnormalities of birds at Kesterson Reservoir in the early 1980s, studies definitively traced the cause to selenium in the agricultural subsurface drainwater in the reservoir (Suter, 1993). Because of this, and because of the well-known history of death, teratogenesis, and reproductive impairment caused by selenium in agricultural drainwater elsewhere (reviewed in Skorupa, 1998), the primary contaminant of concern in this monitoring program is selenium. Other inorganic constituents of potential toxicological interest in drainage water include boron, molybdenum, arsenic and chromium (Klasing and Pilch, 1988; SJVDP, 1990a; CVRWQCB, 1998).

Selenium Ecological Risk Guidelines

The assessment of the risks that selenium poses to fish and wildlife can be difficult due to the complex nature of selenium cycling in aquatic ecosystems (Lemly and Smith, 1987). Early assessments developed avian risk thresholds through evaluating bird egg concentrations and relating those to levels of teratogenesis (developmental abnormalities) and reproductive impairment (Skorupa and Ohlendorf, 1991). In 1993, to evaluate the risks of the Grassland Bypass Project on biotic resources in Mud and Salt Sloughs, a set of Ecological Risk Guidelines based on selenium in water, sediment, and residues in several biotic tissues were developed by a subcommittee of the San Luis Drain Re-Use Technical Advisory Committee (CAST, 1994; Engberg, et.al., 1998). These guidelines (as recently modified: Table 1) are based on a large number of laboratory and field studies, most of which are summarized in Skorupa et al. (1996) and Lemly (1993). In areas where the potential for selenium exposure to fish and wildlife resources exists, these selenium risk guidelines can be used to trigger appropriate actions by resource managers, regulatory agencies, and dischargers. For the GBP the

Table 1. Recommended Ecological Risk Guidelines for Selenium Concentrations.

Medium	Effects on	Units	No Effect	Concern	Toxicity
Warmwater Fish (whole body)	fish growth/condition/survival	mg/kg (dry weight)	< 4	4-9	> 9
Vegetation (as diet)	bird reproduction	mg/kg (dry weight)	< 3	3-7	> 7
Invertebrates (as diet)	bird reproduction	mg/kg (dry weight)	< 3	3-7	> 7
Sediment	fish and bird reproduction	mg/kg (dry weight)	< 2	2-4	> 4
Water (total recoverable Se)	fish and bird reproduction (via foodchain)	µg/L	< 2	2-5	> 5
Avian egg	egg hatchability	mg/kg (dry weight)	< 6	6-10	> 10

Notes

- These guidelines, except those for avian eggs, are intended to be population based. Thus, trends in means over time should be evaluated. Guidelines for avian eggs are based on individual level response thresholds (e.g., Heinz, 1996; Skorupa, 1998)
- A tiered approach is suggested with whole body fish being the most meaningful in assessment of ecological risk in a flowing system.
- The warmwater fish (whole body) Concern threshold is based on adverse effects on the survival of juvenile bluegill sunfish experimentally fed selenium enriched diets for 90 days (Cleveland et al., 1993). It is the geometric mean of the "no observable effect level" and the "lowest observable effect level."
- The Toxicity threshold for warmwater fish (whole body) is the concentration at which 10% of juvenile fish are killed (DeForest et al., 1999).
- The guidelines for vegetation and invertebrates are based on dietary effects on reproduction in chickens, quail and ducks (Wilber, 1980; Martin, 1988; Heinz, 1996).
- If invertebrate selenium concentrations exceed 6 mg/kg then avian eggs should be monitored (Heinz et al., 1989; Stanley et al., 1996).

selenium risk guidelines have been divided into three levels: No Effect, Concern, and Toxicity.

In the No Effect range risks to sensitive species are not likely. As new information becomes available it should be evaluated to determine if the No Effect level should be adjusted. Since the potential for selenium exposure exists, periodic monitoring of water and biota is appropriate.

Within the Concern range there may be risk to sensitive species, and contaminant concentrations in water, sediment, and biota should be monitored on a regular basis. Immediate actions to prevent selenium concentrations from increasing should be evaluated and implemented if appropriate. Long-term actions to reduce selenium risks should be developed and implemented. Research on effects on sensitive or listed species may be appropriate.

Within the Toxicity range, adverse affects are more likely across a broader range of species, and sensitive or listed species would be at greater risk. These conditions will warrant immediate action to reduce selenium exposure through disruption of pathways, reduction of selenium loads, or other appropriate actions. More detailed monitoring, studies on site-specific effects, and studies of pathways of selenium contamination may be appropriate and necessary. Long-term actions to reduce selenium risks should be developed and implemented.

The guidelines (except those for avian eggs) are intended to be population based. Therefore they should be used for evaluating population means rather than contaminant concentrations in individuals.

Warmwater Fish

The warmwater fish guidelines (Table 1) refer to concentrations of selenium in warmwater fish that adversely affect the fish themselves. The original 1993 fish guidelines have been replaced by explicitly "warmwater fish" guidelines in recognition of the evidence from the literature that coldwater fish (salmon and trout) are more sensitive to selenium than warmwater fish and that GBP monitoring data available is limited to warmwater fish. Although a coldwater fish guideline is not proposed here, a discussion of selenium effects on coldwater fish is provided in this section since the best information currently available happens to be very site-specific to the GBP area (Merced River and downstream San Joaquin River).

The Concern threshold for warmwater fish has been kept at about 4 mg/kg (all fish data are whole body, dry weight). Experimental data reported in the literature may be interpreted to support a range of thresholds around this value. In particular, bluegill sunfish dietary and waterborne toxicity data in Cleveland et al. (1993) can be used to support warmwater fish Concern thresholds of 3.3 mg/kg, 3.4 mg/kg, 3.9 mg/kg, or 5.9 mg/kg. Bluegill sunfish are warmwater fish that are found in the sloughs in the GBP area, and the Cleveland et al. (1993) study yielded the best available data on warmwater fish toxicity applicable to GBP.

Cleveland et al. (1993) found no adverse effects after 59 days of exposure to concentrations of dietary selenium that resulted in a bluegill tissue concentration of 2.7 mg/kg no observable effect concentration (NOEC). Fifty nine days of exposure to dietary concentrations that resulted in tissue concentrations of 4.2 mg/kg lowest observable effect concentration (LOEC) caused a significant increase in mortality relative to controls. Following the USEPA method (Stephan et al., 1985) employed by DeForest et al. (1999), the tissue threshold is calculated as the geometric mean of the NOEC and the LOEC. Application of the USEPA procedure to these data yields a Toxicity threshold of 3.4 mg/kg. A similar analysis of a water-borne selenium exposure experiment (Cleveland et al., 1993) yields a threshold value of 3.3 mg/kg.

Other data in Cleveland et al. (1993) may be interpreted to support a threshold closer to 4 mg/kg or a threshold of 5.9 mg/kg. The experiments of Cleveland et al. (1993) suggest that selenium concentrations in fish tissues do not reach equilibrium until at least 90 days of dietary exposure (Figure 3 in Cleveland et al., 1993). This appears consistent with the finding, summarized below, that in the field, selenium concentrations in fish are best predicted by water concentrations averaged over the entire period of one to seven months prior to the date the fish is sampled. In deriving a tissue threshold, there then appears to be some support for using the relationship between dietary concentration and tissue concentration at 90 days rather than 59 days. After 90 days of dietary exposure bluegill with a tissue selenium concentration of 3.3 mg/kg did not exhibit adverse effects that were significantly greater than controls, but bluegill with a tissue concentration of 4.6 mg/kg experienced significantly increased mortality. Bluegill with a tissue concentration of 7.5 mg/kg had three times the mortality of controls, but that difference in mortality was not statistically significant at the 95% level of confidence (Table 4 and Figure 3 in Cleveland et al., 1993). However, the condition factor (a measure of weight relative to length) of the fish at 7.5 mg/kg, was significantly worse than controls. Depending on whether or not the significant mortality at a tissue concentration of 4.7 mg/kg is treated as anomalous, the LOEC would be either 4.7 mg/kg or 7.5 mg/kg. Corresponding thresholds would be 3.9 mg/kg (geometric mean of 3.3 mg/kg and 4.6 mg/kg) or 5.9 mg/kg (geometric mean of 4.6 mg/kg and 7.5 mg/kg) respectively. Given the range of possible threshold values discussed above, the Concern threshold of 4 mg/kg listed in Table 1 was not changed from the original 1993 threshold. However, considering that these data do not include adverse effects on reproduction which may be affected at lower concentrations, this threshold may not be fully protective of sensitive warmwater fish species.

The Toxicity threshold for warmwater fish (whole body) of 9 mg/kg is recommended by DeForest et al. (1999). In the analysis of DeForest et al. (1999) the threshold represents an EC_{10}, that is, the concentration at which 10 percent of fish are affected. DeForest et al. (1999) excluded some toxicity data from their analysis that could support a lower threshold (Cleveland et al., 1993). Also, reproductive impairment may occur at lower selenium concentrations, but too few data are available to do a similar analysis on this effect. Therefore, this Toxicity threshold may not be fully protective of sensitive warmwater fish species.

Coldwater Fish

Testing fall run chinook salmon from the Merced River, Hamilton et al. (1990) found that salmon fry growth was significantly reduced compared to controls after 30 and 60 days of being fed a diet (containing mosquitofish from the SLD) having a selenium concentration of 3.2 mg/kg dry weight. After 90 days of that diet, the selenium concentration in the salmon fry averaged 2.7 mg/kg whole body, dry weight. This fish tissue concentration was the lowest observable effect concentration (LOEC). The no observable effect concentration (NOEC) in salmon fry tissue was 0.8 mg/kg. Following the USEPA method (Stephan et al., 1985) employed by DeForest et al. (1999), the tissue threshold is calculated as the geometric mean of the NOEC and the LOEC. This procedure applied to the Hamilton et al. (1990) SLD data yields a threshold of 1.5 mg/kg (geometric mean of 0.8 and 2.7 mg/kg). It should be noted that this threshold may incorporate the interacting effects of other toxic constituents of drainwater that may have been assimilated by the SLD mosquitofish that were used as feed in the Hamilton, et al. (1990) experiments. Furthermore, at the time of these experiments (1985), the SLD held agricultural drainwater from the Westlands, an area adjacent to the Grasslands area. Therefore, although these are the most site-specific selenium toxicity data available, these data may not perfectly match the current risk of toxicity to coldwater fish in the San Joaquin River due to agricultural drainwater from the GBP. Although the sloughs affected by the GBP have coldwater beneficial uses designated by the Central Valley Regional Water Quality Control Board, the fish community principally consists of warmwater species. A temporary barrier is installed seasonally across the San Joaquin River to exclude chinook salmon (a coldwater species) from these sloughs and from the San Joaquin River upstream of its confluence with the Merced River. Additionally, any application of the coldwater fish risk guidelines should take into account the fact that many coldwater fish are anadromous, and therefore feed in the selenium-contaminated portion of the San Joaquin River for a limited period of time— a brief period in their juvenile stage as they migrate downstream to the ocean.

A Toxicity threshold for coldwater fish (whole body) of 9 mg/kg has been recommended by DeForest et al. (1999). In the analysis by DeForest et al. (1999) the Toxicity threshold represents an EC_{10}, that is, the concentration at which 10 percent of fish are affected. DeForest et al. (1999) excluded site-specific and longer term data (Hamilton et al., 1990) which could support lower thresholds. For example, to derive their Toxicity threshold for coldwater fish, DeForest et al. (1999) used only the 60 day growth data in Hamilton et al. (1999); they disregarded the 90 day mortality data in Hamilton et al. (1999) that would have yielded a Toxicity threshold (corresponding to 10% mortality) of 1.7 mg/kg. In addition, the DeForest et al. (1999) analysis focused on growth and mortality. Reproductive impairment may occur at lower selenium concentrations, but too few data are available to do a similar analysis on this effect. Therefore, this threshold may not fully protect sensitive coldwater fish species.

Vegetation and Invertebrates

The guidelines for vegetation (as diet) and invertebrates (as diet) refer to selenium concentrations in plants and invertebrates affecting birds that eat these items. These guidelines are mainly based on experiments in which seleniferous grain or artificial diets spiked with selenomethionine were fed to chickens, quail or ducks resulting in reproductive impairment (Wilber, 1980; Martin, 1988; Heinz, 1996). The Concern threshold for vegetation is 3 mg/kg (dry weight) and the Toxicity threshold is 7 mg/kg. The invertebrate Concern threshold and Toxicity threshold are the same as those for vegetation.

Water

Fish and wildlife are much more sensitive to selenium through dietary exposure from the aquatic food chain than by direct waterborne exposure. Therefore the guidelines for water reflect water concentrations associated with threshold levels of food chain exposure (Hermanutz et al., 1990; Maier and Knight, 1994), rather than concentrations of selenium in water that directly affect fish and wildlife. The Concern threshold is 2 μg/L and the Toxicity threshold is 5 μg/L.

Sediment

As with water, the principal risk of sediment to fish and wildlife is via the aquatic food chain. Therefore the sediment guidelines are based on sediment concentrations as predictors of adverse biological effects through the food chain (USFWS, 1990; Van Derveer and Canton, 1997). The Concern threshold for sediment (dry weight) is 2 mg/kg and the Toxicity threshold is 4 mg/kg.

Bird Eggs

Bird eggs are particularly good indicators of selenium contamination in local ecosystems (Heinz, 1996). However, the interpretation of selenium concentrations in bird eggs in the GBP area is complicated by the proximity of contaminated and uncontaminated sites and by the variation in foraging ranges among bird species. Relative to the guidelines originally used for the GBP, the guidelines used here for bird eggs have been revised upward based on recent studies of hatchability of ibis, mallard, and stilt eggs (Henny and Herron, 1989; Heinz, 1996; USDI-BOR/FWS/GS/BIA, 1998). The Concern threshold has been raised from 3 to 6 mg/kg dry weight, and the Toxicity threshold has been raised from 8 to 10 mg/kg dry weight.

Selenium Ecological Risk Index

Several years after the risk guidelines were developed for the GBP, Lemly (1995, 1996) published a risk index designed to provide an estimate of ecosystem-level effects of selenium. Lemly's assessment procedure sums the effects of selenium on various ecosystem components to yield a characterization of overall hazard to aquatic life. The procedure involves determining an index of toxicity for each component, then adding these indexes together to yield a single index, often known as the Lemly Index.

In contrast to the ecological risk guidelines outlined in Table 1, the component indexes of the Lemly Index are based on maximum contaminant concentrations rather than means. Therefore, the Lemly Index is sensitive to brief spikes in contaminant levels, but is unaffected by prevailing contaminant levels. Furthermore, the Lemly Index is strongly dependent on sampling periods and sampling frequency, yet Lemly provided no sampling protocol. For these reasons, there is a need to develop a new protocol and index that replaces Lemly's categorical rating format (low, medium, high) with a direct estimate of the probability of adverse effects (e.g.10%+ probability of reproductive impairment). Despite the weaknesses of the Lemly Index, we continue to use it for comparative purposes as long as it remains the best available overall index of the ecological risk of selenium.

Boron Ecological Risk Guidelines

The dietary and tissue concentrations of boron associated with toxic effects on fish and wildlife are not as well known as for selenium. The effects of dietary exposures and waterborne exposures (without dietary exposures) are known for some taxa (Table 2), but there are as yet no definitive data associating tissue concentrations with adverse effects in fish and invertebrates. Boron concentrations as low as 0.1 mg/l in water may adversely affect reproduction of sensitive fish species (review in NIWQP, 1998).

Methods

The role of the California Department of Fish and Game (CDFG) and the USFWS in this interagency program is to implement the bio-monitoring portion of the Compliance Monitoring Program. The methods used by the CDFG and USFWS are described in the Quality Assurance Project Plan for Use and Operation of the Grassland Bypass Project (QAPP; Entrix, Inc., 1997). These methods are also based on standard operating procedures described in Standard Operation Procedures for Environmental Contaminant Operations (USFWS, 1995) and standards used by the other agencies participating in the compliance monitoring program. Deviations from the QAPP that have occurred since 1996 will be discussed later in this section.

To obtain baseline data for this Project, the USFWS began sampling in March 1992, after the reuse of the SLD was initially proposed by the USBR in 1991. The

Table 2. Recommended Ecological Risk Guidelines for Boron Concentrations.

Medium	Effects on	Units	No Effect	Concern	Toxicity
Water	fish (catfish and trout embryos)	mg/L	< 5	5-25	> 25
Water	invertebrates (*Daphnia*)	mg/L	< 6	6-13	> 13
Water	vegetation (crops and aquatic plants)	mg/L	< 0.5	0.5-10	> 10
Waterfowl diet	duckling growth	mg/kg (dry weight)		> 30	
Waterfowl egg	embryo mortality	mg/kg (dry weight)	<1		>30

Notes
- Water guidelines for invertebrates are based on the "no observed adverse effects level" and "lowest observed adverse effects level" for Daphnia magna (Lewis and Valentine 1981; Gersich 1984).
- Waterfowl diet guidelines are based on mallard ducks (Smith and Anders 1989).
- The waterfowl egg no effect level is based on poultry data from Romanoff and Romanoff (1949) and San Joaquin Valley field data for reference sites (R. L. Hothem and D. Welsh; J. P. Skorupa et al.).
- The waterfowl egg Concern and Toxicity thresholds are based on Smith and Anders (1989), Stanley et al. (1996), and the "order-of-magnitude rule of thumb" (toxicity at about 10 times background concentrations).
- The US Environmental Protection Agency's suggested no adverse response level for drinking water is 0.6 mg/L.

CDFG began sampling in August of 1993. USFWS and CDFG sampling plans before the reopening of the SLD and the early drafts of the monitoring plan were mutually influencing. Therefore, methods used by both agencies before the final approval of the QAPP are, except for a few minor differences, identical to the methods ultimately approved by the Data Collection and Reporting Team. The sampling schedule, though, as discussed below, now follows a regular timetable.

Matrices Sampled

Samples of the biota were collected at each site and analyzed for selenium and boron. Aquatic specimens were collected with hand nets, seine nets and by electrofishing. Mosquitofish (*Gambusia affinis*), inland silversides (*Menidia beryllina*), red shiners (*Cyprinella lutrensis*), fathead minnows (*Pimephales promelas*), carp (*Cyprinus carpio*), white catfish (*Ameiurus catus*), and green sunfish (*Lepomis cyanellus*) were the principal species of fish collected. Waterboatmen (family: Corixidae), backswimmers (family: Notonectidae), and red crayfish (*Procambarus clarkii*) were the principal invertebrates collected. Separation of biological samples from unwanted material also collected in the nets was accomplished by using stainless steel or Teflon sieves, and glass (or enamel) pans pre-rinsed with de-ionized water then native water. To the extent possible, three replicate, composite samples (minimum 5 individuals totaling at least 2 grams for each composite) of each primary species listed above were collected, but other species were also collected. Fish species were analyzed as composite whole-body samples except as noted below. Estimates of a conversion factor for relating selenium concentration in skeletal muscle (M) to whole-body concentrations (WB) range from M=0.6 x WB for many freshwater fish (Lemly and Smith, 1987) to M=0.045+1.23 x WB for bluegills and M=-0.39+1.32 x WB for largemouth bass (Saiki et al., 1991).

Between 1992 and 1999, frog tadpoles occasionally collected from Mud Slough and Salt Slough sites were archived. In 1999 these archived samples were analyzed. Additional samples were collected and analyzed from these sites in 2000 and 2001.

Analyses of fish samples collected from the San Joaquin River sites and Mud Slough (Sites E, G, and H) were prioritized to first meet the objectives of the Compliance Monitoring Plan (Section 4.5.1.4). Supplemental fish samples were analyzed only when baseline biota target species and sample sizes could not be obtained.

In WYs 1999, 2000, and 2001 several samples of fish and invertebrates submitted for analysis were of insufficient mass to permit individual measurement of the water content (percent moisture) of the sample, a measurement used to calculate the dry weight selenium concentration in the sample. For these samples (designated with asterisk on the graphs), an average percent moisture was calculated from the percent moisture measurements of comparable samples in the closest possible conditions of sampling location, time, species, and size of organism. This average percent moisture was used to calculate the dry weight selenium concentration. Selenium concentrations discussed in text and displayed in figures below are averages of composite sample concentrations except for bird eggs and except where otherwise stated.

The seed heads of wetland plants that provide food for waterfowl were collected along the sloughs in the late summer of the years 1995-2001. Much of this plant material was archived until analyzed in the years 2000 and 2001.

Waterfowl and/or shorebird eggs, depending on availability, were collected from areas adjacent to Mud Slough and the SLD in the spring of each year from 1996 through 2001. In addition, in 1992 snowy egret and black-crowned night heron eggs were collected at East Big Lake, which has served as a reference sampling site for the USFWS. Bird eggs were analyzed individually, and the results are discussed and displayed below as individual concentrations and geometric means.

Graphs of whole-body and avian egg selenium concentrations presented in this report include indications of the threshold concentrations delimiting the risk ranges listed above (Table 1). The threshold between the No Effect zone and the Concern zone is indicated by a horizontal line of short dashes; the Toxicity threshold is marked on each graph by a horizontal line of long dashes.

All biota samples were kept on ice or on dry ice while in the field then kept frozen to 0° C during storage and shipment. For all samples, after freeze drying, homogenization, and nitric-perchloric digestion, total selenium was determined by hydride generation atomic absorption spectrophotometry and boron was determined by inductively coupled (argon) plasma spectroscopy.

Sampling Sites

Between 1992 and 1999 biological samples have been collected from two sites on Salt Slough, five sites on Mud Slough, two sites in the SLD, two sites on the San Joaquin River, and one reference site that does not receive selenium-contaminated drainwater (East Big Lake). Beginning in 1995, sampling efforts were concentrated on the seven sites (Figure 1) identified in the Compliance Monitoring Plan: four sites on Mud Slough (C, D, E, and I), one on Salt Slough (F) and two San Joaquin River sites (G and H). Site C is located upstream of where the Grassland Bypass discharges into Mud Slough. Site D is located immediately downstream of the discharge point. Site I is a small, seasonally flooded backwater area fed by Mud Slough and is located approximately 1 mile downstream from Site D. Site E is located further downstream where Mud Slough crosses State Highway 140. To assess the mitigative effects of drainwater removal from Salt Slough, one sample point, Site F, is located on the San Luis National Wildlife Refuge approximately 2 miles upstream of where State Highway 165 crosses Salt Slough. Site G is located on the San Joaquin River at Fremont Ford, upstream of the Mud Slough confluence, while Site H is located on the San Joaquin River 200 meters upstream of the confluence of the main branch of the Merced River, downstream of the Mud Slough confluence. Sites C, D, F, and I are monitored by the USFWS while CDFG monitored Sites E, G, and H.

During the WY 2001, biological sampling in Mud Slough was moved from Site I to a new site (Site I2) about 0.5 km upstream of Site I. The new site has a larger, more permanent backwater area.

Sampling Times

Baseline sampling conducted by the USFWS occurred monthly during the spring and summer of 1992 and then less frequently during 1993 and 1994. Baseline sampling by CDFG occurred during the summer and fall of 1993 and then resumed in the spring of 1996. Between 1992 and 1995 sampling by either the CDFG and the USFWS occurred at least once every season. Experience and interagency discussions led to the identification of four sampling times based on historic water use and drainage practices and on seasonal use of wetland resources by fish and wildlife. Biota sampling since 1995 has been synchronized to occur during the months of November, March, June, and August. Since 1996, avian eggs have been collected in May and June.

Statistical Analysis

Student's 2-tail t-tests were used to compare means of concentrations for groups of samples collected at different times at the sampling sites (unpaired samples with unequal variances).

Selenium Hazard Assessment

The protocol proposed by Lemly (1995, 1996) was used to estimate the overall hazard of selenium to the ecosystems affected by the GBP. The implementation of the protocol presented here incorporates data for water from Central Valley Regional Water Quality Control Board and data for sediment from the USBR in addition to biological data collected by the USFWS, CDFG, and CH2M HILL. In accordance with Lemly's protocol, the assessments use the highest (rather than the mean) concentrations of selenium found in each of the ecosystem components (Appendix A).

Data from the biological sampling in November 1996, shortly after GBP initiation, were excluded from the WY 1997 hazard assessments because temporarily extremely high concentrations of selenium in some fish may have been due to those fish having been flushed out of the previously stagnant, evapo-concentrated SLD. Very high levels of selenium in the water associated with storm flows were not excluded because elevated concentrations persisted long enough (especially in February 1998) potentially to affect the ecosystem adversely.

Concentrations of selenium in fish eggs were estimated from whole-body concentrations using the conversion factor (fish egg selenium = fish whole-body selenium x 3.3) recommended in Lemly (1995, 1996).

In this report, care has been taken to ensure that Lemly index for the area potentially adversely affected by the Grassland Bypass Project incorporates only contaminant levels that are due to this project. Therefore, although Figure 31 displays selenium concentrations in killdeer eggs collected along the San Luis Drain in the Kesterson Reservoir area, those data are not used in the calculation of the Lemly index because of the possibility that some of the most elevated selenium concentrations in eggs are due to killdeer foraging in areas of the Kesterson Reservoir residually contaminated by selenium from Westlands area farms predating this project.

Site E (lower Mud Slough) and the San Joaquin River (SJR) sites (G and H) cannot be rated as to overall hazard of selenium because not all media have been collected to assess these sites. Further confounding the evaluation at these sites is the prevalence of introduced fish species with broad environmental tolerances and the limited catch of invertebrates during WY 1999 and WY 2000.

Departures from the Compliance Monitoring Plan and Quality Assurance Project Plan

To ensure reliable and consistent data, the USFWS and the CDFG followed the procedures specified in the Compliance Monitoring Plan and the Quality Assurance Project Plan (QAPP) with the exceptions listed below.

External quality assurance samples (QAPP Appendix A, Section 7) were not submitted to analytical labs with GBP biological samples before January of 1998. External quality assurance samples are biological materials (e.g. powdered chicken egg, shark liver) with certified concentrations of the analytes of concern (selenium, boron), supplied by third party laboratories. The analyte concentrations in these samples are known to the agencies submitting the samples, but not known to the laboratory doing the analysis. This blind test of laboratory analytical precision supplements the internal quality control procedures of the analytical laboratory. Internal quality control protocols specified in the QAPP (procedural blanks, duplicate samples, and spiked samples) have been followed throughout the history of GBP biological sampling.

The USFWS used stainless steel (rather than Teflon) strainers for sorting small fish (QAPP Appendix A, Section 4.7).

For some species at some locations it has not been practical at some times to collect the full target minimum numbers of individuals and/or mass per sample that are specified in the Compliance Monitoring Plan (Section 4.5.1.4) and the QAPP (Appendix A, Section 4.5).

From 1992 through 1997 all biological samples collected by the USFWS (except bird eggs in 1996 and 1997) were analyzed by Environmental Trace Laboratory at the University of Missouri in accordance with the QAPP (Appendix A, Section 6.1). Bird egg samples collected in 1996 and 1997 were analyzed at Trace Element Research Laboratory (TERL) at Texas A & M University, a USFWS contract laboratory. All biological samples collected in 1998 were analyzed at TERL. TERL is subject to the same performance standards as Environmental Trace Substance Laboratory, therefore, the GBP quality assurance objectives (QAPP Table 1) apply to analytical results from TERL. All biological samples were analyzed at the Water Pollution Control Laboratory of the CDFG in Rancho Cordova, California, after this laboratory was screened and approved by the GBP Quality Control Officer.

Seine net mesh size was increased from 3/16 inch to 1/4 inch after the first two pre-Project collections in 1993 from sampling sites E, G, and H (QAPP Appendix A, Section 4.6). This change in sampling gear resulted in significant declines in catch abundance of smaller forage fish without altering diversity of representative assemblages. Data collected from 1993 sampling efforts at these sites were not included in making quantitative spatial or temporal comparisons between sites unless otherwise noted. At Sites C, D, I, and F, 1/8 inch mesh seines were used from 1992 through 1998. Since 1999 a 3/16 inch mesh bag seine has been used at these sites in place of the 1/8 inch mesh bag seine that was previously used by the USFWS.

As discussed previously, biological sampling in Mud Slough was moved from Site I to Site I2, a new site about 0.5 km upstream with a larger, more permanent backwater area.

Results

Salt Slough (Site F)

Fish (Whole-Body)

Salt Slough is a principal wetland water supply channel from which drainwater has been removed by the GBP. Concentrations of selenium in Salt Slough fish composite samples declined during the first year of operation of the GBP but have stabilized since then at levels well below the Concern threshold (Figures 2 and 3), with the exception of March 1998 when concentrations rose in the aftermath of storms that resulted in substantial releases of drainwater into Salt Slough. The average of all composite samples of fish at this site in WY 2001 was 2.6 mg/kg (n=51), substantially below the warmwater fish Concern threshold (4 mg/kg), significantly below the pre-Project average (5.3 mg/kg, n=66; $p<0.0001$), but not different from the average for the previous year (2.6 mg/kg, n=70; $p=0.7$). In June 2001 the selenium concentration (5.0 mg/kg dry weight, calculated from wet weight using average percent moisture of 79.3%) in a single 1.8 gram logperch (*Percina caprodes*) exceeded the Concern threshold for warmwater fish (4 mg/kg).

Tadpoles

Frog tadpoles (mainly bullfrog, *Rana catesbeiana*) have been collected only occasionally in the GBP area. Results suggest that in Salt Slough, selenium concentrations in tadpoles, as in fish and invertebrates, declined after implementation of the GBP (Figure 4). A composite sample of four bullfrog tadpoles collected in Salt Slough in August 1999 had about half the selenium concentration (2.6 mg/kg) of a single bullfrog tadpole collected in March 1993 (5.8 mg/kg). Selenium concentrations appeared to rise in the summer of 2000 (2.9 mg/kg in a composite sample of three bullfrog tadpoles in June 2000 (7.5 mg/kg in a composite sample of three tadpoles, and 2.3 mg/kg in a single, 19 g frog in August 2000), but returned to lower levels in the summer of 2001 (3.8 mg/kg in a single, 0.4 g tadpole in June 2001; 2.5 mg/kg in a composite sample of 13 tadpoles in August 2001). However, sample sizes are very small for drawing conclusions about year-to-year trends.

Invertebrates

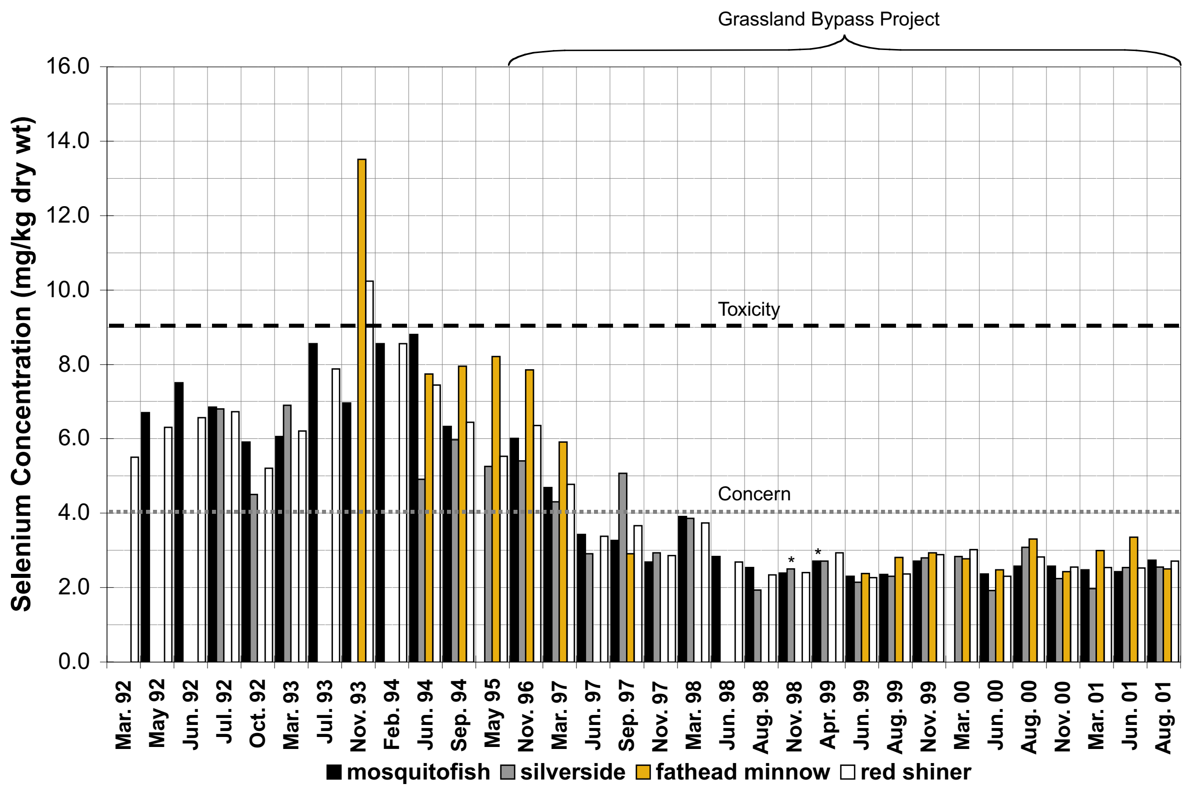
During WY 2001, selenium concentrations in invertebrates collected from Salt Slough (Figure 5) remained within the range of concentrations associated with no known adverse effects (<3 mg/kg) on animals that eat invertebrates. The mean concentration of selenium in all invertebrate samples collected in WY 2001 (2.2 mg/kg, n=9) was significantly below ($p<0.00001$) the pre-Project mean (4.4 mg/kg, n=27), but not significantly different ($p=0.63$) from the WY 2000 mean (2.1 mg/kg, n=5).

Mud Slough 0.4 km above SLD Outfall (Site C)

Fish (Whole-Body)

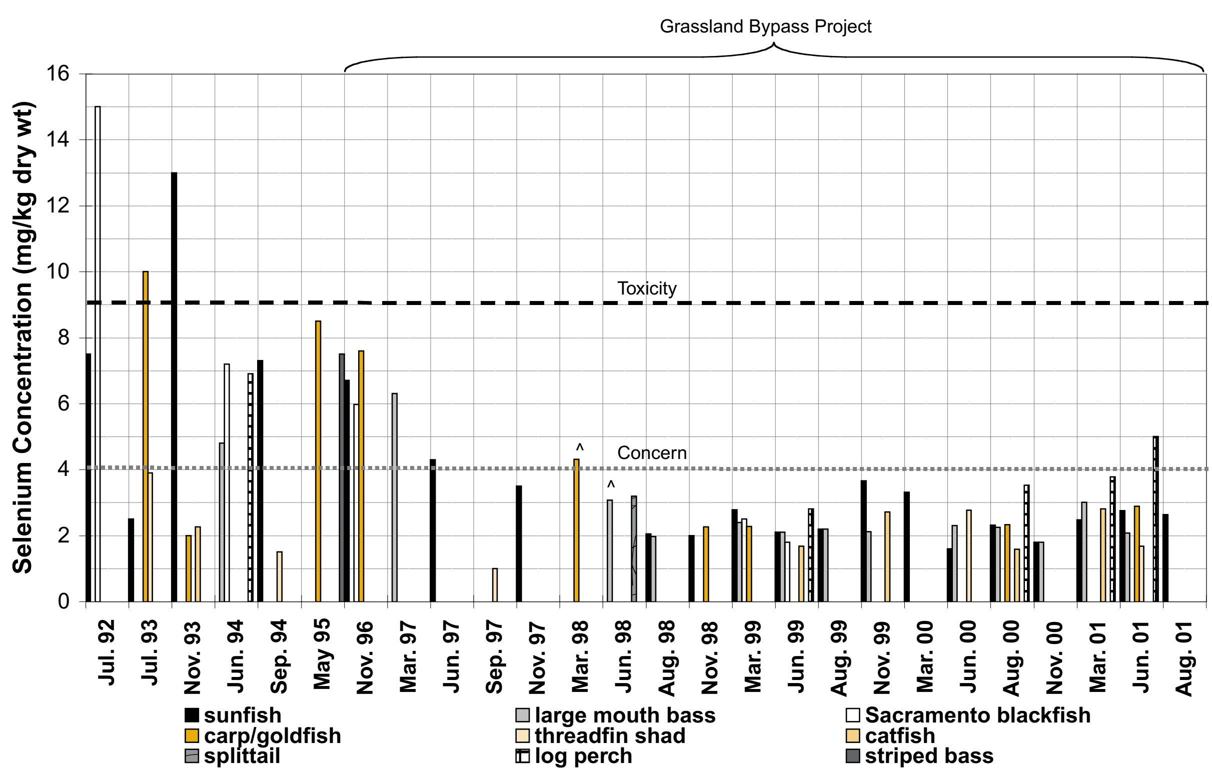
During the fifth year of operation of the GBP, average selenium concentration in fish just above the SLD (3.0 mg/kg, n=63) remained the same as in the previous year (3.0 mg/kg, n=65, $p=0.84$) and not significantly different ($p=0.2$) from the pre-Project average at this site (2.8 mg/kg, n=37; Figures 6 and 7). The warmwater fish Concern threshold (4 mg/kg; see Table 1) was exceeded by the average selenium concentrations in fathead minnow and/or red shiner composite samples in every sampling period during the water year (November 2000 one composite fathead minnow sample 6.7 mg/kg, average of three composite red shiner samples 4.7 mg/kg; March 2001 one composite fathead minnow sample 4.4 mg/kg; June 2001 one composite fathead minnow sample 5.0 mg/kg; August 2001 average of three red shiner composite samples (6.35 mg/kg). Elevated average selenium concentrations in some samples at this site may be due to the influence of individual fish swimming upstream from the more contaminated reach of Mud Slough below the discharge of the San Luis Drain.

Figure 2. Selenium in small fish in Salt Slough (Site F). Each bar represents an average of composite samples.



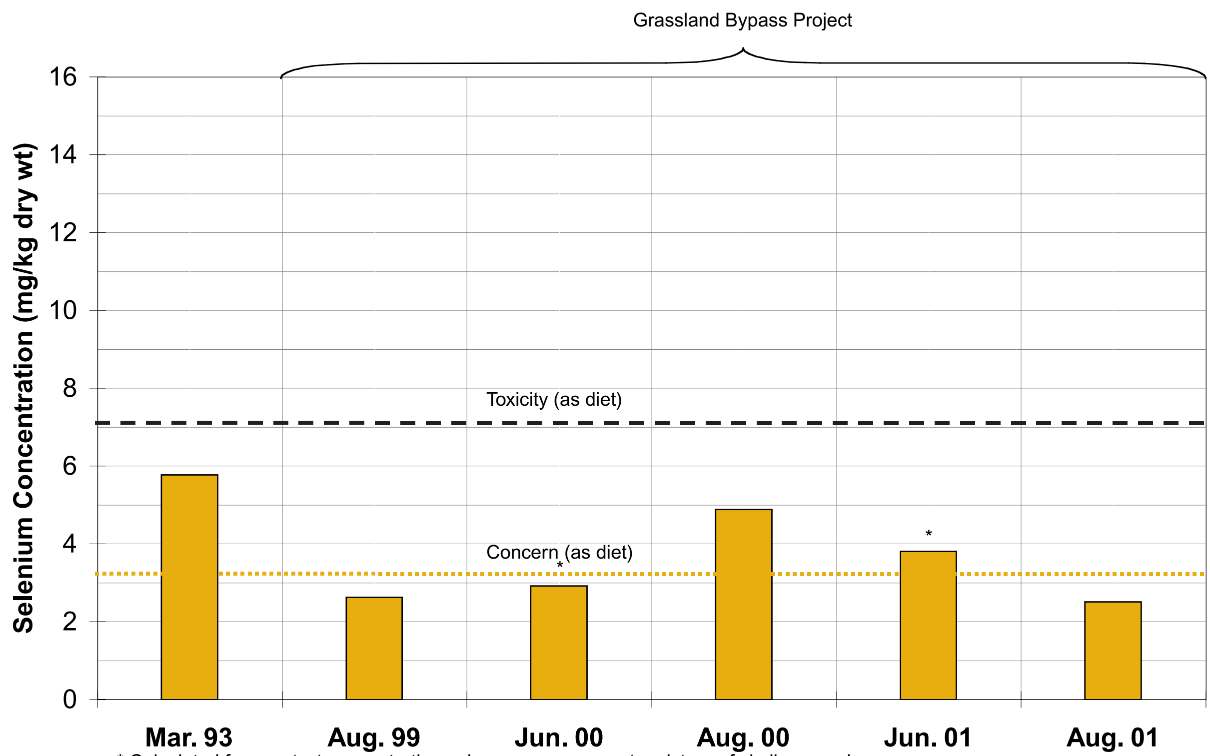
* Calculated from wet wt concentration using average percent moisture of similar samples.

Figure 3. Selenium in medium-size fish in Salt Slough (Site F).



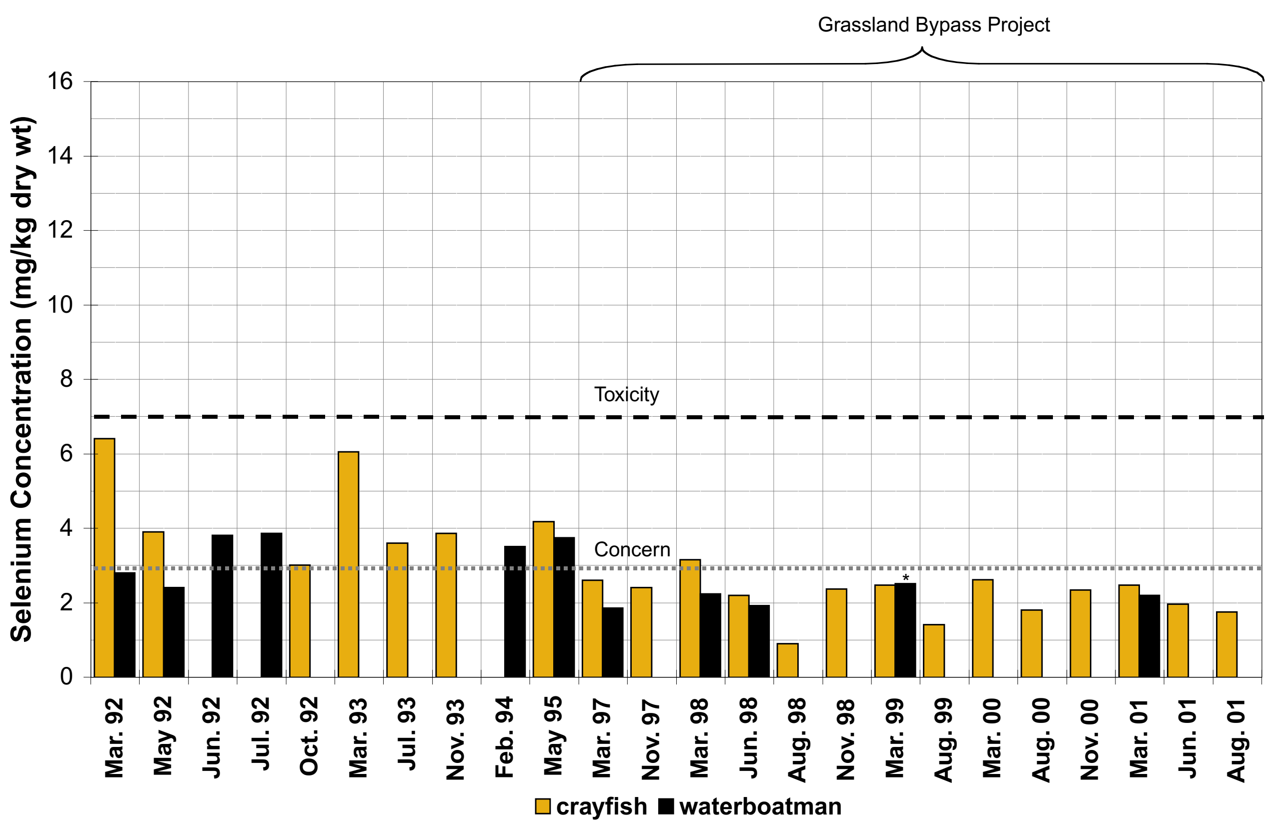
^muscle only

Figure 4. Selenium in bullfrogs/tadpoles in Salt Slough (Site F).



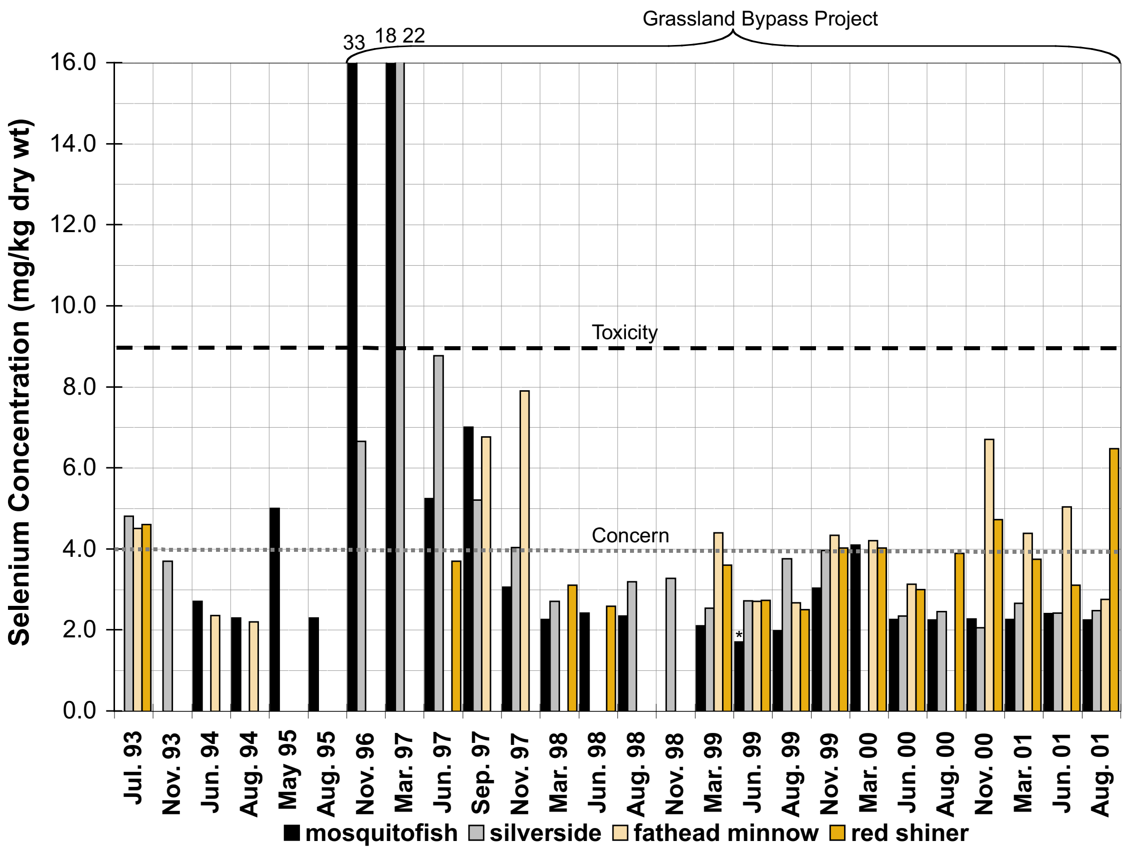
* Calculated from wet wt concentration using average percent moisture of similar samples.

Figure 5. Selenium in invertebrates in Salt Slough (Site F).



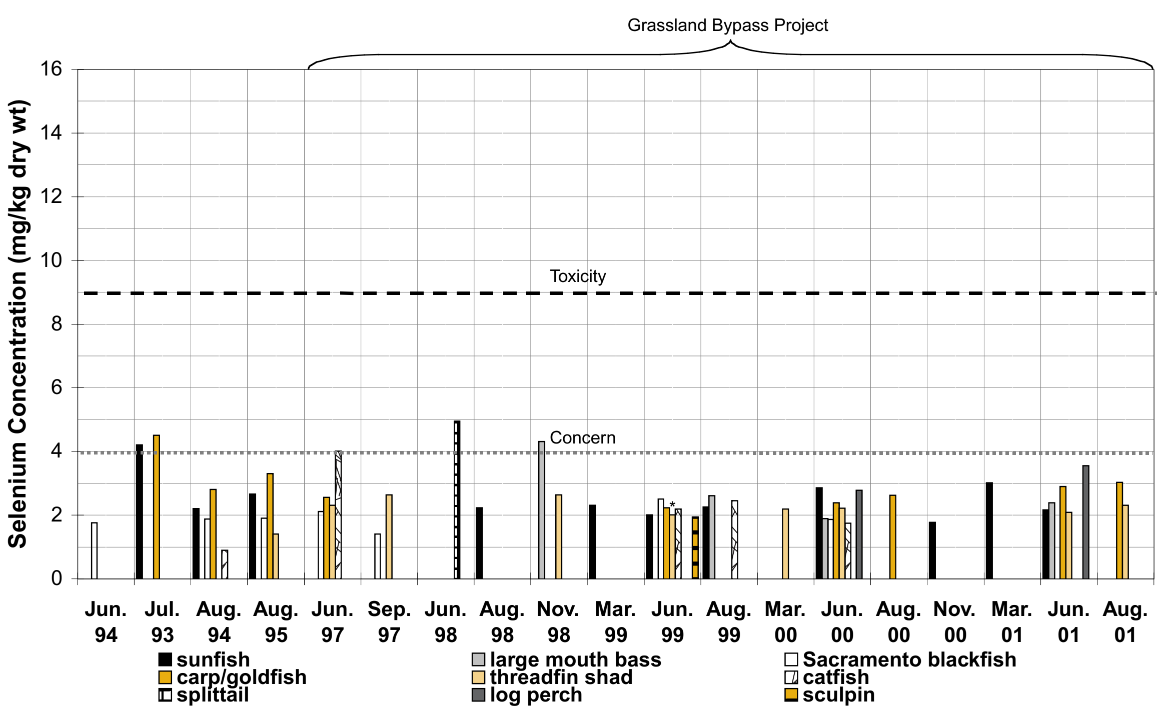
* Calculated from wet wt concentration using average percent moisture of similar samples.

Figure 6. Selenium in small fish in Mud Slough above the San Luis Drain discharge (Site C).



* Calculated from wet wt concentration using average percent moisture of similar samples.

Figure 7. Selenium in medium-size fish in Mud Slough above the San Luis Drain discharge (Site C).



* Calculated from wet wt concentration using average percent moisture of similar samples.

Tadpoles

At Site C, a single bullfrog tadpole was collected in March 2001. The selenium concentration in this sample (3.5 mg/kg) was in the middle of the range of concentrations in tadpole samples collected previously at this site (Figure 8), above the threshold of Concern (3 mg/kg) for dietary effects on birds that may forage on tadpoles. No tadpoles were collected at this site prior to WY 1999.

Invertebrates

In the fifth year of operation of the GBP, selenium concentrations in invertebrates at Site C remained generally about the same as in previous years, below the Concern threshold (Figure 9). The average concentration in all invertebrate composite samples in WY 2001 was 1.8 mg/kg (n=14), not significantly different (p=0.23) from the previous year (1.7 mg/kg, n=10), and not significantly different (p=0.56) from the pre-Project average (2.0 mg/kg, n=15).

Mud Slough 0.2 km below SLD Outfall (Site D)

Fish (Whole-Body)

At Site D, about 200 m below the SLD outfall, the average selenium concentration in fish (7.3 mg/kg, n=42) increased significantly ($p<0.0001$) above the average for the previous year (5.0 mg/kg, n=39) and significantly ($p<0.0001$) above the pre-Project mean (3.8 mg/kg, n=67; Figures 10 and 11). As in previous years, within WY 2001, selenium concentrations in fish exhibited significant ($p<0.00001$) seasonal variation in addition to the secular year-to-year increase (November 2000-March 2001 average: 3.7 mg/kg, n=11; June-August 2001 average: 8.6 mg/kg, n=31).

Tadpoles

A single 11-gram composite sample of four bullfrog tadpoles collected in March at this site had a selenium concentration of 4.0 mg/kg (Figure 12). Tadpoles have only be collected occasionally in Mud Slough below the San Luis Drain outfall, and selenium concentrations have always been within the range that is of concern as diet for birds that prey on aquatic vertebrates (3-7 mg/kg).

Invertebrates

Average selenium concentration in invertebrate samples at Site D (4.4 mg/kg, n=8) increased significantly (p=0.037) in the fifth year of operation of the GBP compared to the previous year (2.2 mg/kg, n=2; Figure 13). However this may be due to seasonal differences and the exigencies of sampling at a site where invertebrates have been scarce throughout the history of the GBP monitoring program. In the fifth year of the GBP, no invertebrates where collected here in November, but in the previous year, the only invertebrates collected in sufficient numbers to analyze were collected in November, a time of seasonally low selenium concentrations.

Mud Slough 1.5 km below SLD Outfall (Site I/I2)

During the fifth year of the GBP, biological monitoring was moved from the original Site I to a new site, designated I2, that better serves the purpose for which Site I was chosen. Site I was originally selected to represent backwater conditions along the adversely affected reach of Mud Slough. This site was located along Mud Slough about 1.5 km downstream of the SLD outfall where high winter and spring flows in Mud Slough often overtop the slough channel to form a broad, shallow backwater on the east side of the slough. In the early years of monitoring for the GBP, biological monitoring was done at Site I only when this backwater condition coincided with regular monitoring times for the other sites. Therefore, this site was only monitored occasionally. However, this site represented a better measure of the effects of the GBP on Mud Slough biota than Site D because it was further from the diluting influence of aquatic organisms swimming downstream from the cleaner reach of Mud Slough above the outfall of the San Luis Drain. Therefore, from 1999 to 2000, monitoring at this site was increased to four times per year, matching the monitoring at the other biological monitoring sites for this project; monitoring was conducted in the main channel of Mud Slough at this site in addition to or instead of the backwater, depending on backwater conditions. Meanwhile, National Wildlife Refuge staff helped locate a new backwater site along Mud Slough that typically remains inundated throughout the year. This backwater, Site I2, is located about 1 km downstream of the outfall of the San Luis Drain. Monitoring at Site I2 began in March 2001.

Figure 8. Selenium in tadpoles in Mud Slough above the San Luis Drain discharge (Site C).

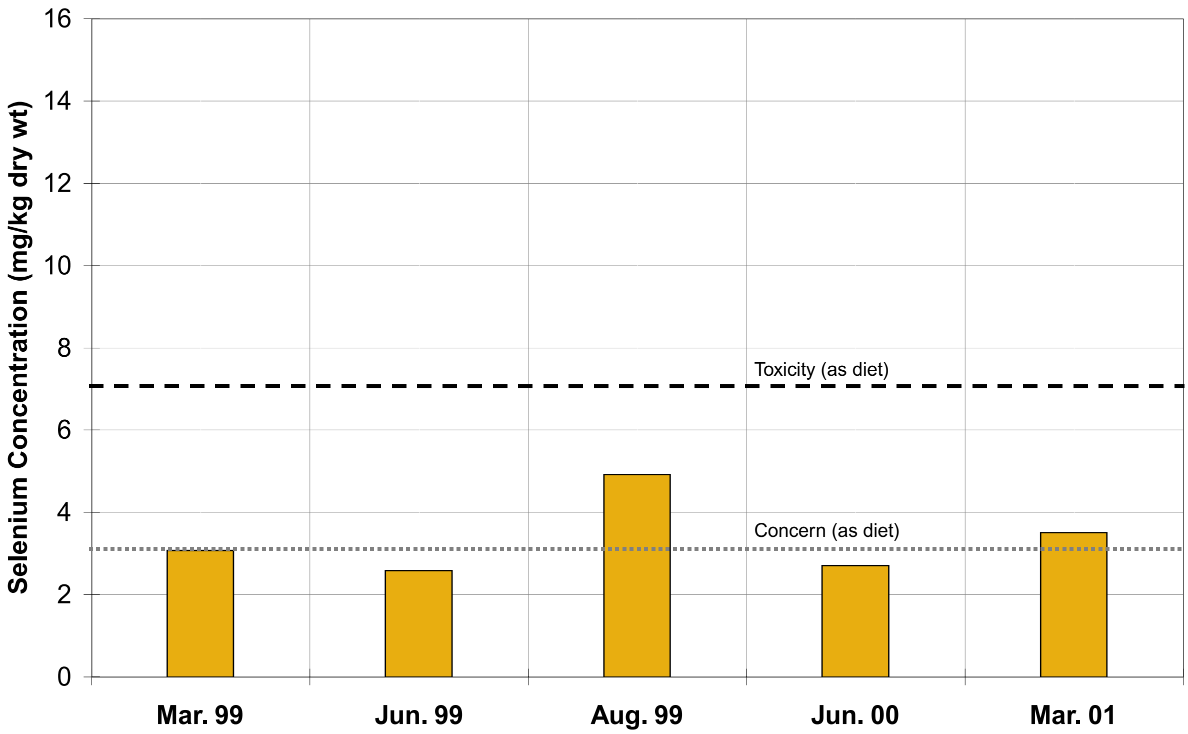
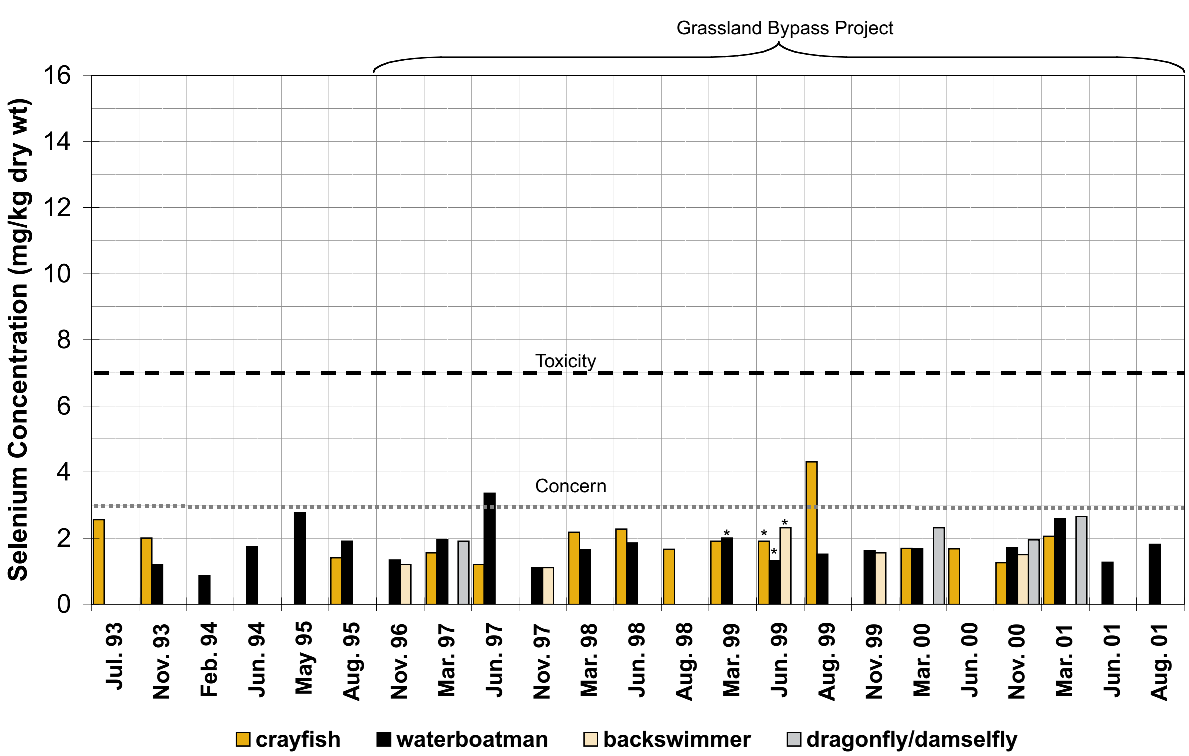
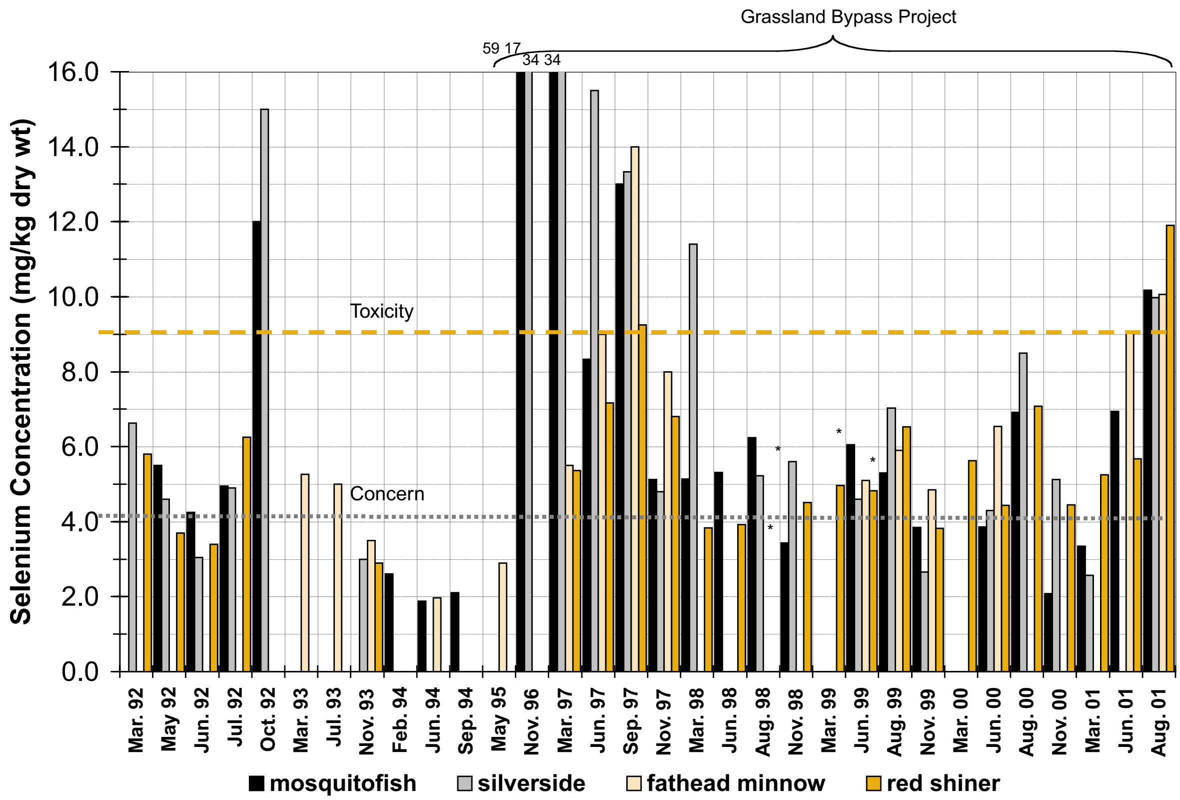


Figure 9. Selenium in invertebrates in Mud Slough above the San Luis Drain discharge (Site C).



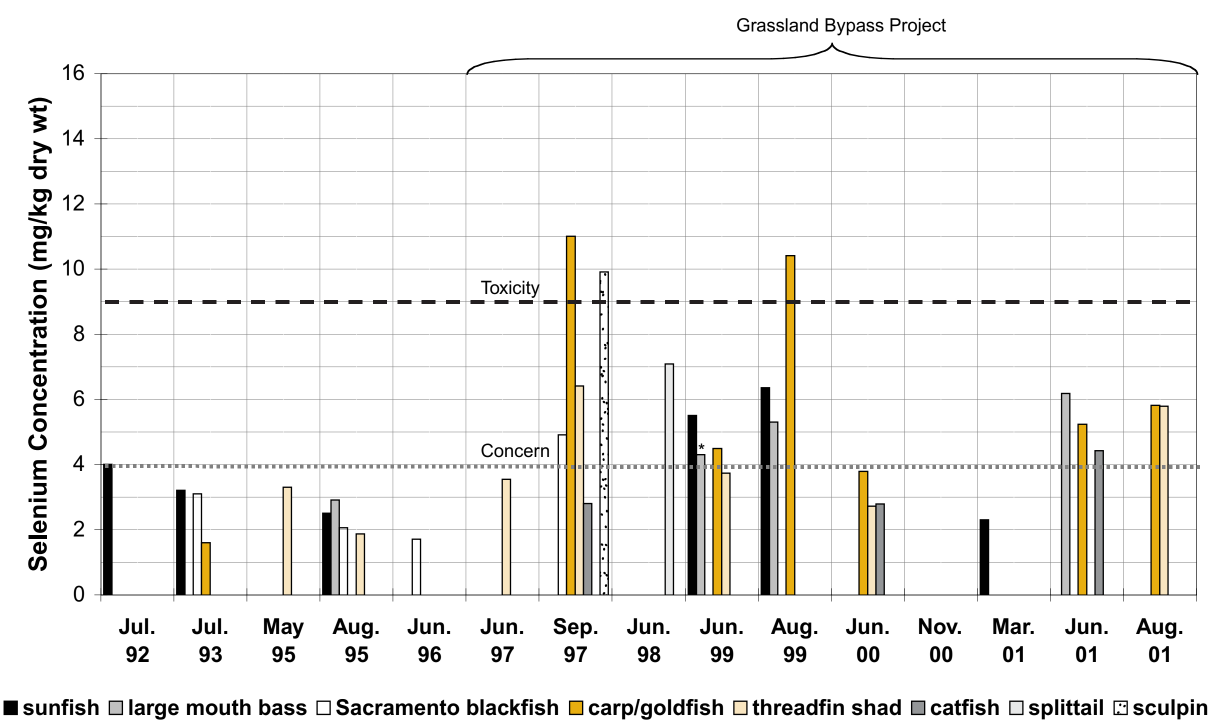
* Calculated from wet wt concentration using average percent moisture of similar samples.

Figure 10. Selenium in small fish in Mud Slough below the San Luis Drain discharge (Site D).



* Calculated from wet wt concentration using average percent moisture of similar samples.

Figure 11. Selenium in medium-size fish in Mud Slough below the San Luis Drain discharge (Site D).



* Calculated from wet wt concentration using average percent moisture of similar samples.

Figure 12. Selenium in tadpoles in Mud Slough below the San Luis Drain discharge (Site D).

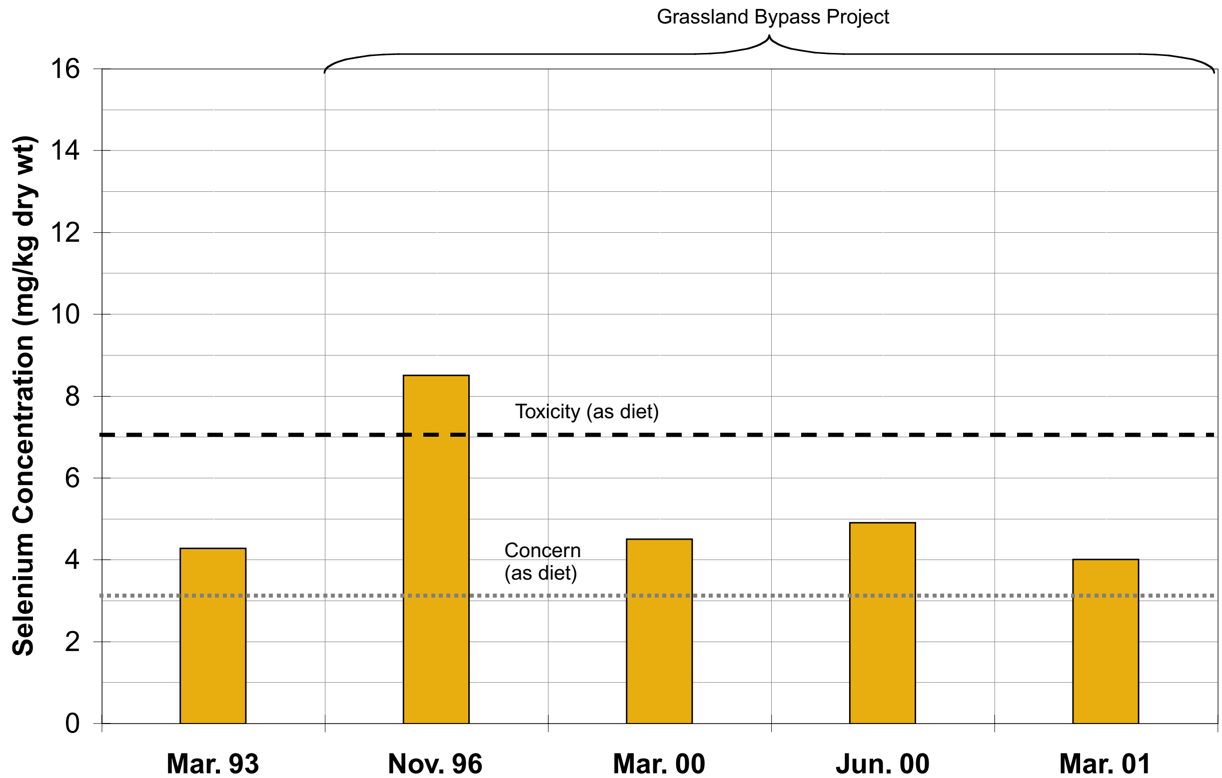
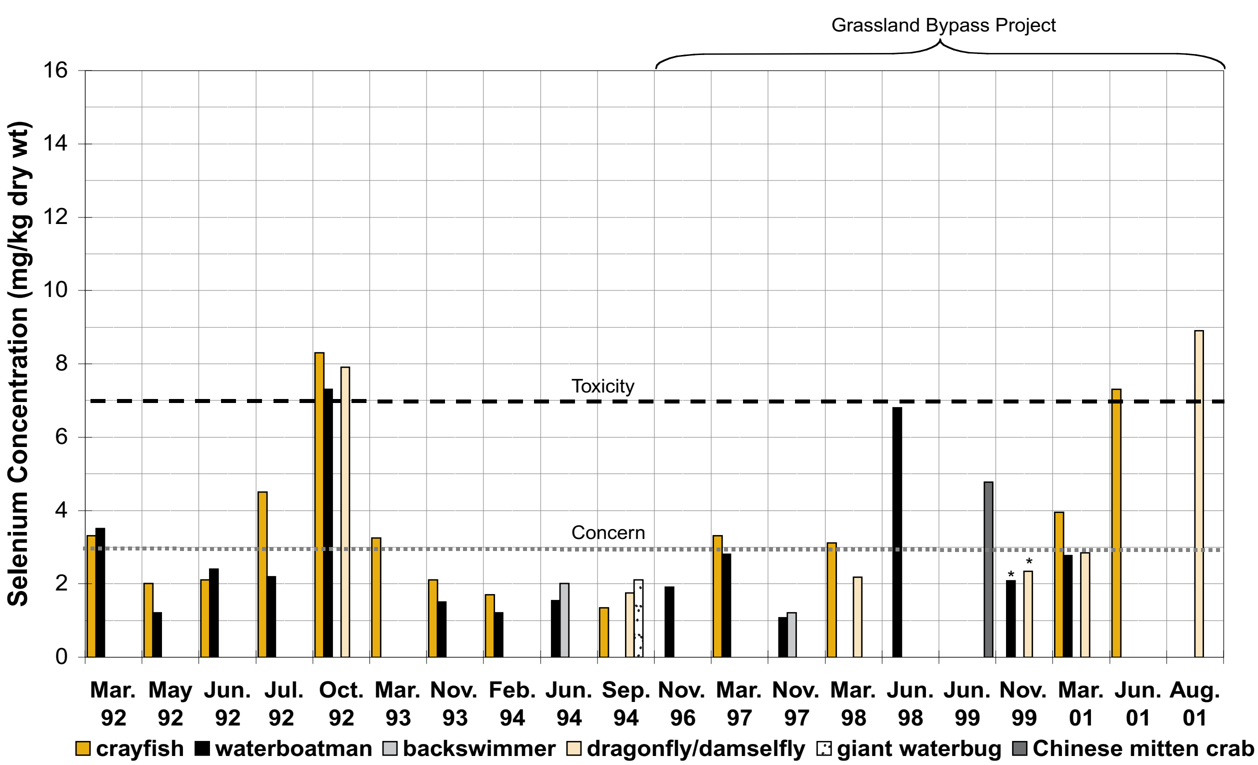


Figure 13. Selenium in invertebrates in Mud Slough below the San Luis Drain discharge (Site D).



* Calculated from wet wt concentration using average percent moisture of similar samples.

Fish (Whole-Body)

At Sites I and I2, average selenium concentration in fish (9.2 mg/kg, n=59) increased significantly (p=0.0002) in the fifth year of the GBP compared to the previous year (7.0 mg/kg, n=47; Figures 14 and 15). Some of this apparent increase could be due to the change in sites from I to I2; however, comparison of the December/November monitoring, which was conducted at the same site (I) both years, suggests a real increase (December 2000 average 6.2 mg/kg, n=6; November 1999 average 5.1 mg/kg, n=7, p=0.078). Furthermore, the year-to-year increase echoes a similar increase upstream at Site D (Figure 10). As at Site D and at Site I in previous years, selenium concentration exhibited a marked seasonal increase (p<0.000001) from early spring (March average 5.1, n=16) to late summer (August average 14.3, n=19). In August at Site I2, selenium concentrations in all fish samples were elevated well into the Toxicity zone both for effects on warmwater fish themselves (>9 mg/kg) and as diet for piscivorous birds (>7 mg/kg).

As in the previous year at Site I, in WY 2001 at Site I2, significantly greater bioaccumulation of selenium appeared to occur compared to Site D (in August 2001, mean of all fish at Site I2: 14.3 mg/kg, n=19; at Site D: 10.0 mg/kg, n=16, p<0.00001). This may in part be a real effect due to more efficient bioaccumulation in the backwater conditions at Site I2. However, it is likely that a principal reason is that composite samples of fish and invertebrates collected at Site D include substantial numbers of individuals that have moved downstream from the cleaner reach of Mud Slough above the outfall of the Drain, thereby diluting the measurements of the effects of drainwater on the biota at Site D.

Tadpoles

Tadpoles have not been collected at this site.

Invertebrates

Average selenium concentration in all invertebrates collected at Sites I and I2 during the fifth year of operation of the GBP (5.1 mg/kg, n=13) was not significantly different (p=0.8) from that of Site I in the previous year (5.6 mg/kg, n=7; Figure 16). However, as with Site D, so few invertebrates can be collected here in sufficient numbers for analysis that year to year comparisons are problematic. All invertebrate samples collected at this site had selenium concentrations above the threshold of Concern for birds that would forage on these invertebrates (3 mg/kg). As with fish at this site, and both fish and invertebrates upstream at Site D, there is significant (p=0.003) cyclic seasonal variation in selenium concentrations in invertebrates at this site (March 2001 average 4.4 mg/kg, n=6; June-August average 6.1 mg/kg, n=5).

Mud Slough at Highway 140 (Site E)

Site E is located in lower Mud Slough downstream from Sites D and I2 but upstream from the confluence of Mud Slough with the San Joaquin River. This site represents the lower, portion of the reach of Mud Slough that is adversely affected by the operation of the Project. At this point along Mud Slough, within the flood plain of the San Joaquin River, flows are slower and more spread out, and flood waters of the San Joaquin River periodically back up into slough, providing some flushing. Selenium in whole body fish and invertebrate samples collected at this site in 1999, 2000 and 2001 confirm the trend of increasing concentrations that is evident at Sites D, I, and I2. Samples at this site are collected by the California Department of Fish & Game.

Fish (Whole-Body)

Selenium concentrations in composite samples of whole-body fish collected during WY 2001 ranged from 6.5 to 13.7 mg/kg (dry weight). The average selenium concentration in whole-body fish (μ= 9.2 mg/kg, n=12) increased significantly (p<0.002[1]) above the average for the previous year (5.9 mg/kg, n=16) and significantly (p<0.000) above the pre-Project average (2.5 mg/kg, n=20; Figure 17). As in previous years, selenium concentrations in fish exhibited seasonal variation in addition to the year-to-year increase (November 2000-March 2001 average: 7.3 mg/kg, n=12; June-August 2001 average: 11.1 mg/kg, n=12). All samples collected in August 2001 exceeded the Toxicity threshold of 9 mg/kg (dry weight).

Invertebrates

Crayfish were not as difficult to catch at this site during WY 2001 as in previous years. Seven composite samples of crayfish collected at this site during WY 2001 had an average selenium concentration of 6.1 mg/kg (dry weight), within the Concern range (3 - 7 mg/kg dry weight) for invertebrates (Figure 18). This was significantly higher than the average selenium concentration of crayfish caught at this site during WY 2000 (μ=2.6, n=4, p<0.002). In August 2001, the average selenium concentration in sampled crayfish was 5.85 mg/kg (dry weight, n=3), exceeding the Concern threshold (4 mg/kg, dry

Figure 14. Selenium in small fish in a Mud Slough backwater below the Drain discharge (Sites I and I2).

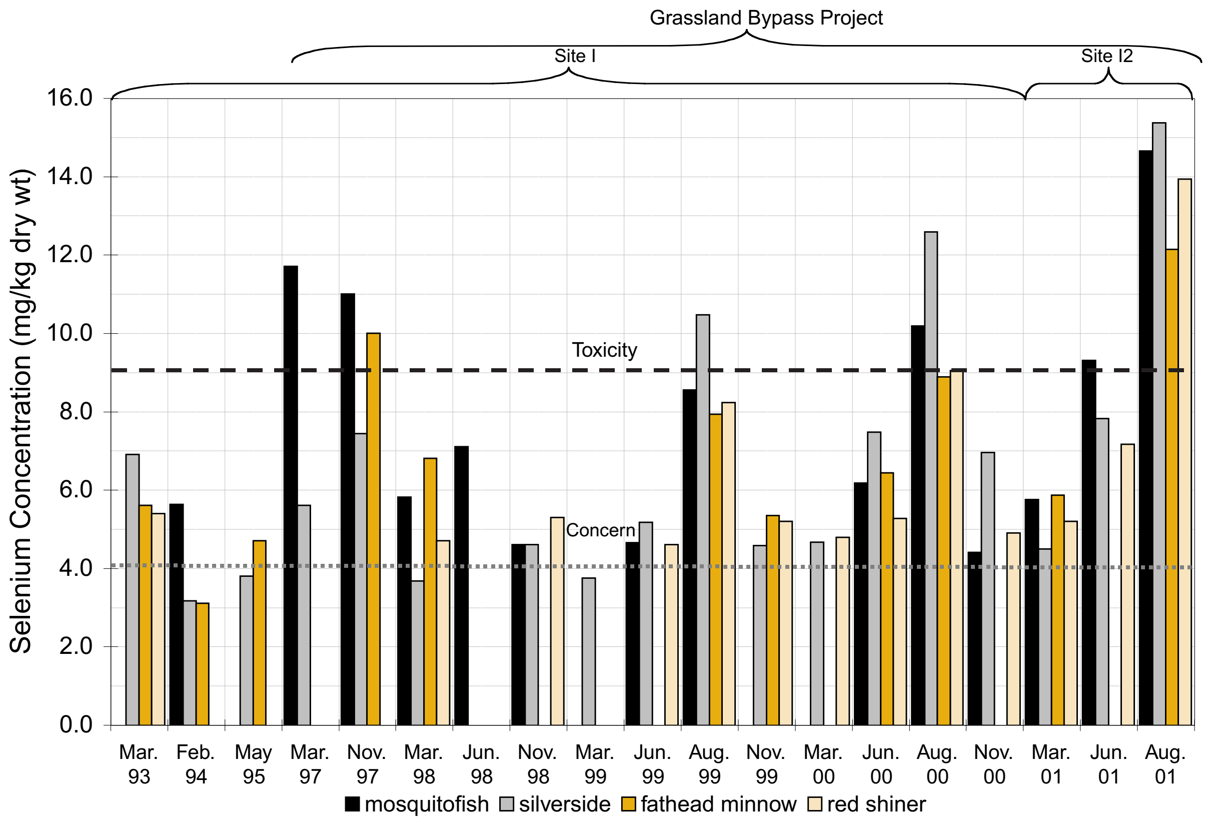


Figure 15. Selenium in medium-size fish in a Mud Slough backwater below the Drain discharge (Sites I and I2).

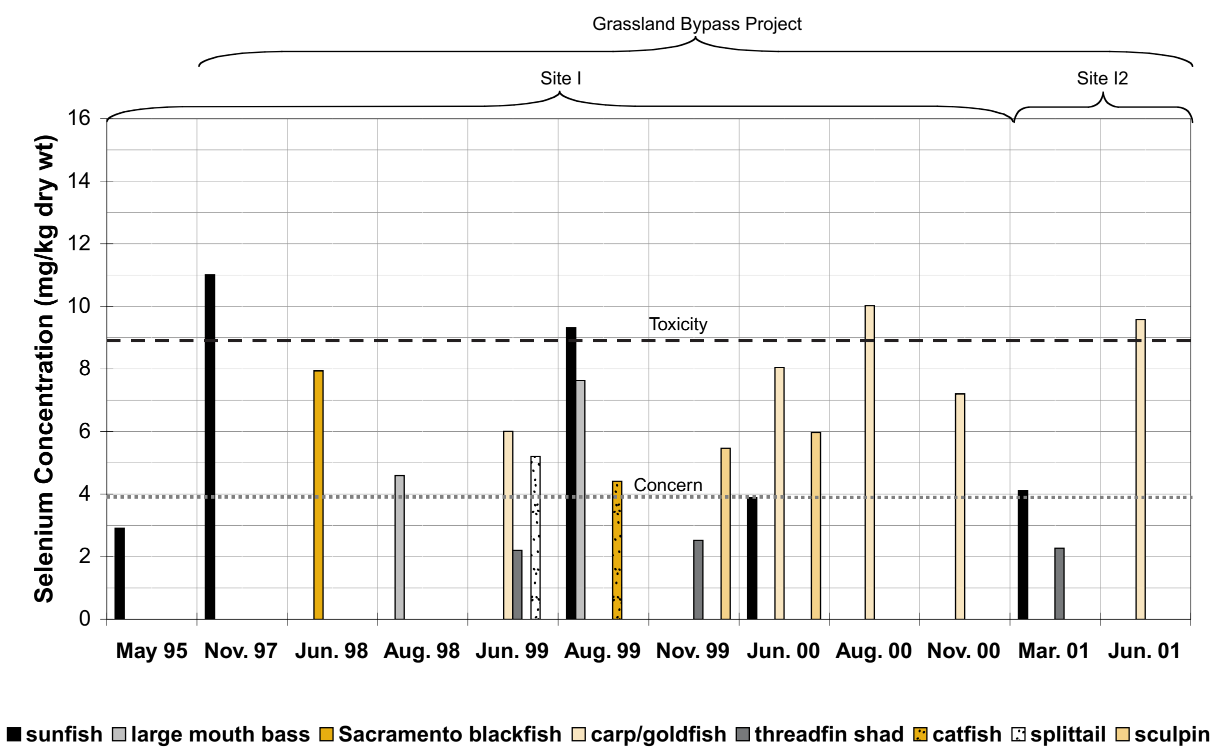
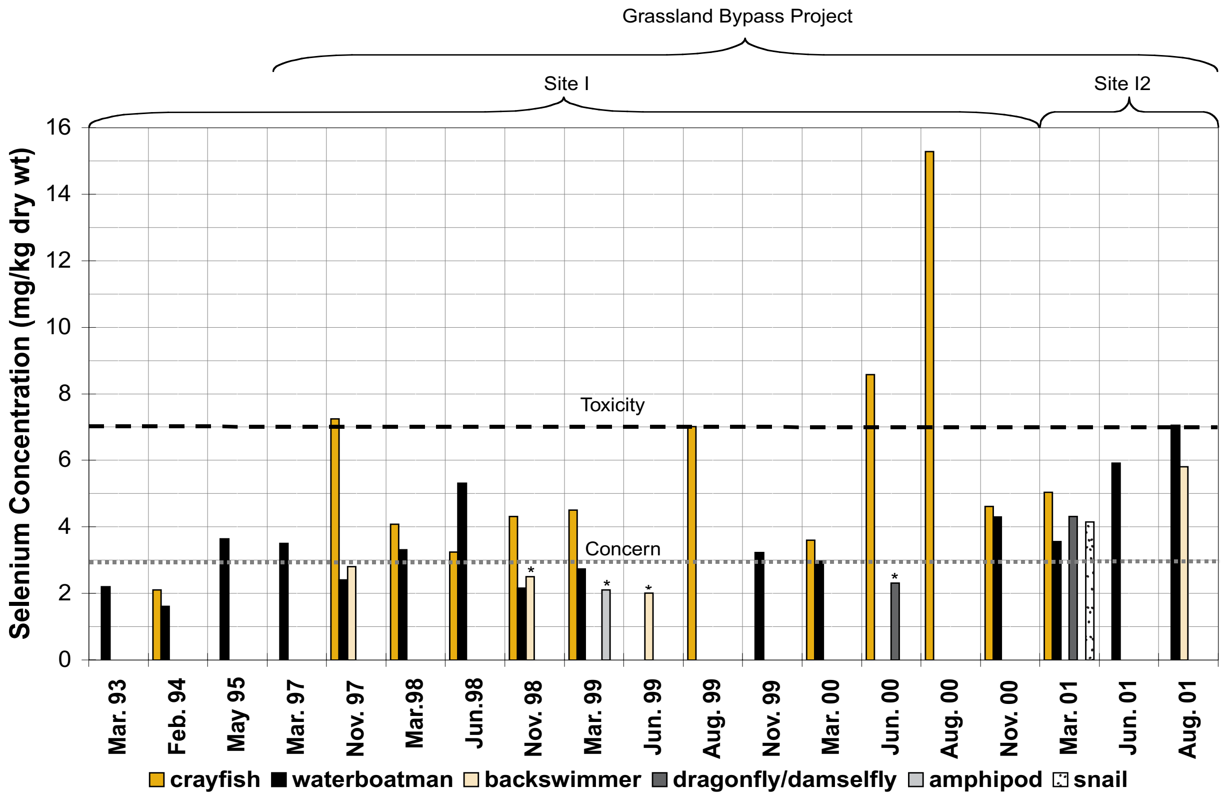
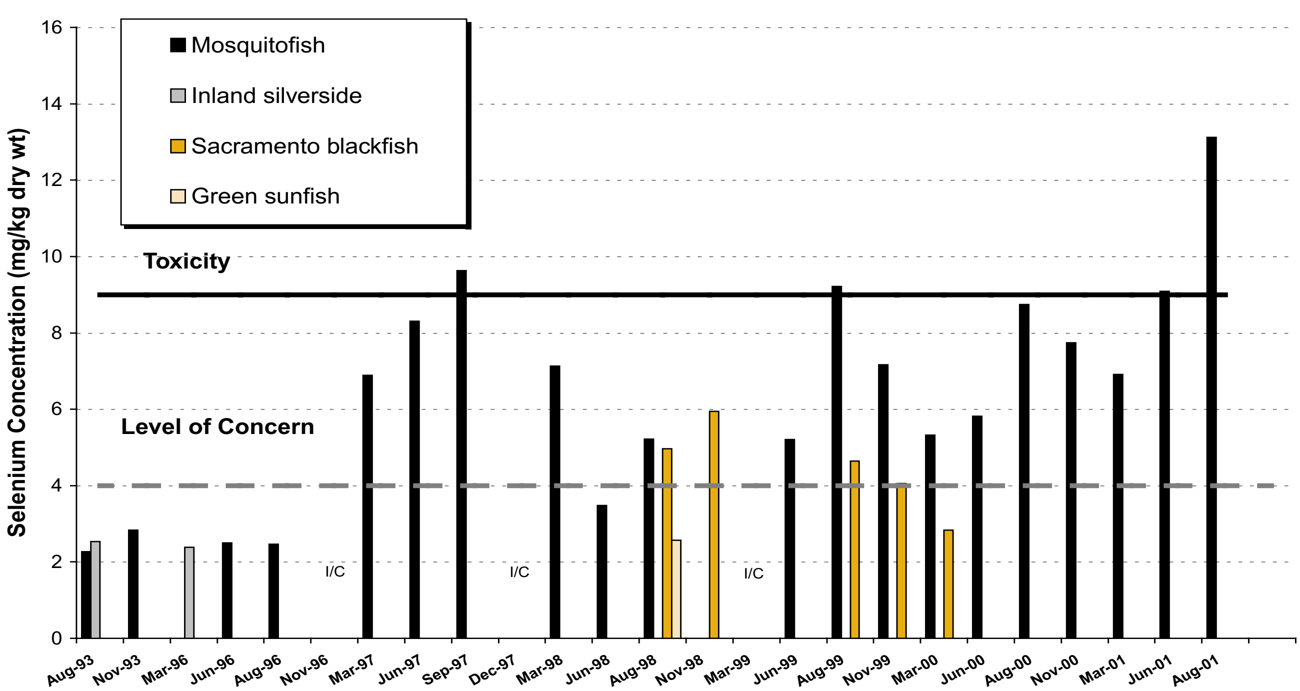


Figure 16. Selenium in Invertebrates in a Mud Slough backwater below the Drain discharge (Sites I and I2).



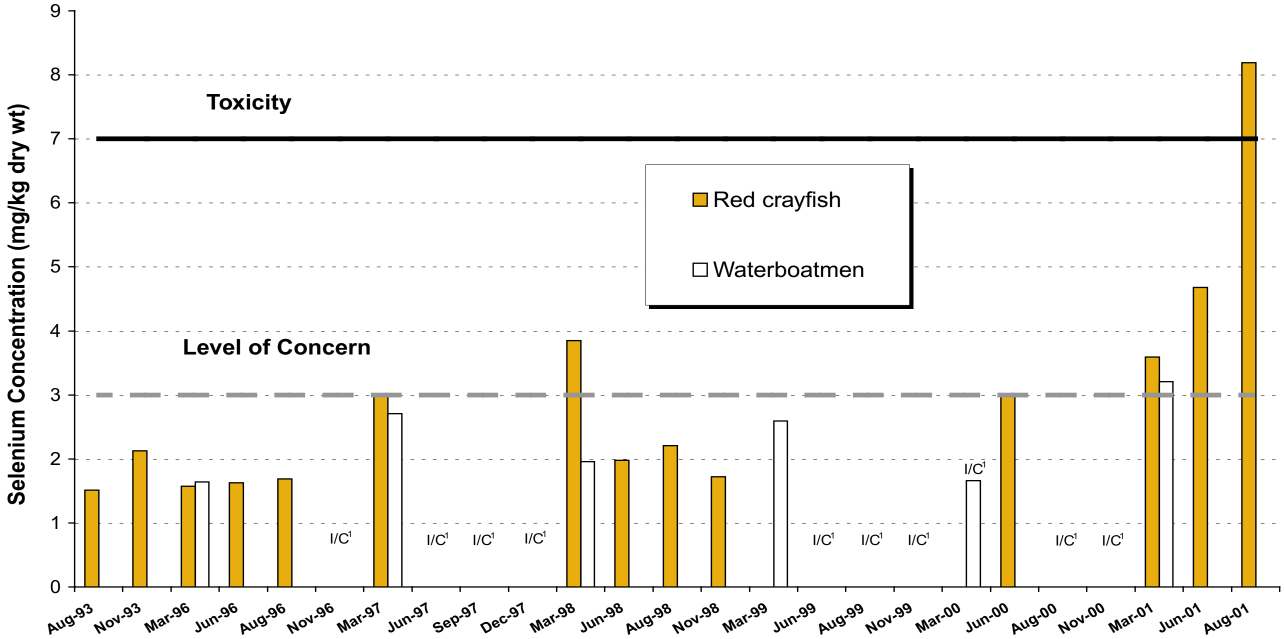
* Calculated from wet wt concentration using average percent moisture of similar samples.

Figure 17. Selenium Concentrations in Whole-Body Fish Tissue from Mud Slough at Hwy 140 (Site E).



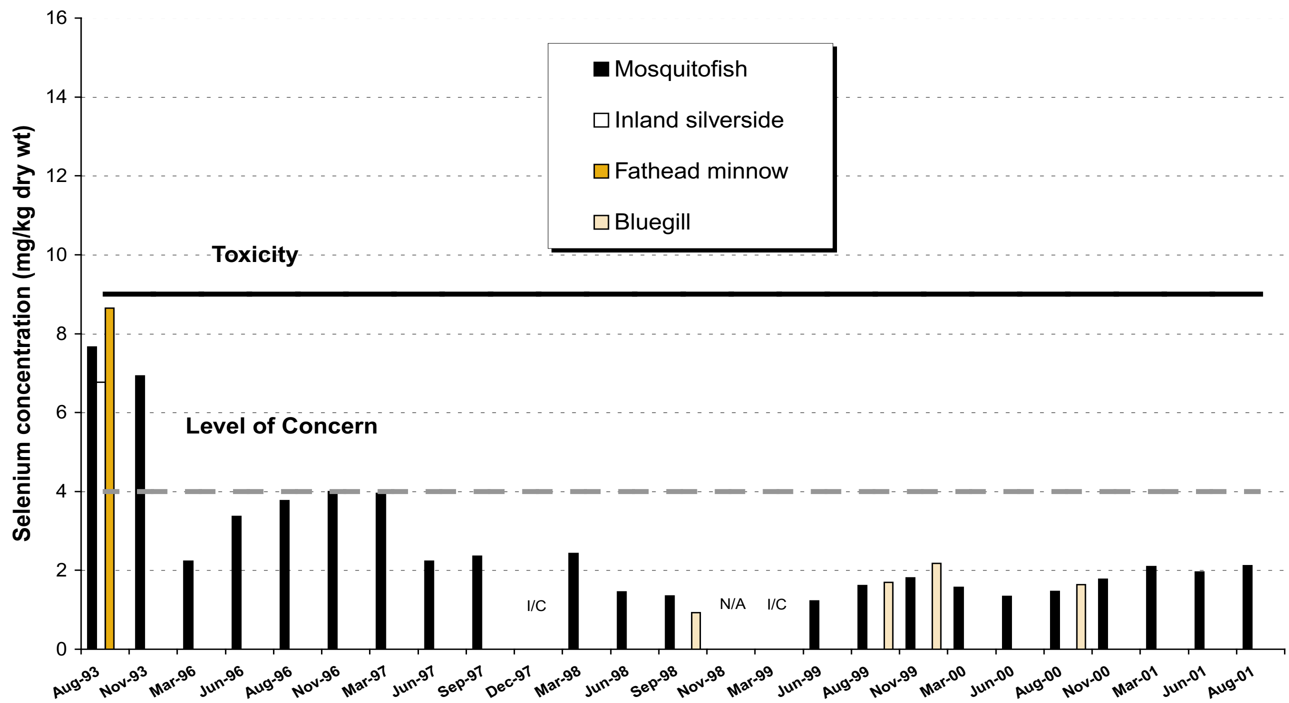
I/C: Insufficient Catch of Targeted Fish Species for Adequate Sample

Figure 18. Selenium Concentration in Invertebrates from Mud Slough at Hwy 140 (Site E).



I/C[1]: Insufficient Catch of Red Crayfish for Adequate Quarterly Sample

Figure 19. Selenium Concentrations in Whole-Body Fish Tissue from the San Joaquin River Upstream of the Mud Slough Confluence (Site G).



I/C: Insufficient Catch of Targeted Fish Species for Adequate Sample
N/A: No Analysis of Collected Samples

weight). Composite samples of waterboatmen collected during March 2001 were slightly above the threshold of Concern (3 mg/kg dry weight), with an average selenium concentration of 3.2 mg/kg (dry weight, n=3). In prior years, annual samples of waterboatmen were below the 3 mg/kg threshold of Concern.

San Joaquin River at Fremont Ford (Site G)

Site G is located is located on the San Joaquin River upstream of the Mud Slough confluence. This site represents the reach of the San Joaquin River that no longer receives agricultural drainwater from the GDA as a result of the GBP.

Fish (Whole-Body)

Similar to the first four years of GBP operation, selenium concentrations in composite samples of fish collected from this site continued to reflect removal of selenium-laden drain water. Selenium concentrations in composite samples of whole-body mosquitofish collected during WY 2001 ranged from 1.6 to 2.4 mg/kg (dry weight), remaining well below the Concern threshold (4 mg/kg dry weight) for warmwater fish (Figure 19). Average selenium concentration for all whole-body fish collected in WY 2001 (μ=2.0, n=12) was higher than that in the previous year (WY 2000, μ=1.6, n=15, $p<0.000$), but less than 4 mg/kg (dry weight) Concern threshold. Selenium concentrations in whole-body fish have decreased significantly from pre-project levels (μ=5.6 mg/kg dry weight, n=21, $p<0.000$), and have consistently been below the Concern range (4–9 mg/kg dry weight).

Invertebrates

Selenium concentrations in all invertebrates from this site were higher than WY 2000 and previous years since project operations began (Figure 20). The nine composite samples of crayfish were collected during WY 2001 had selenium concentrations ranging from 0.9 to 2.4 mg/kg (dry weight), remaining below the 3 mg/kg (dry weight) threshold of Concern for invertebrates as prey items. The average concentration of selenium in crayfish caught at this site during WY 2001 was 1.46 mg/kg (dry weight, n=9) which was significantly greater than the average of crayfish caught during WY 2000 (μ=0.4 mg/kg dry weight, n=8, $p<0.010$). However, the WY 2001 average concentration was significantly less than the pre-project concentration of 3.5 mg/kg (dry weight, n=9, $p<0.004$).

Similar to crayfish, waterboatmen collected from this site during WY 2001 were well below the 3 mg/kg (dry weight) threshold of Concern, with an average selenium concentration of 1.4 mg/kg (dry weight).; this level has consistently remained below the threshold of Concern during all water years since Project operations began.

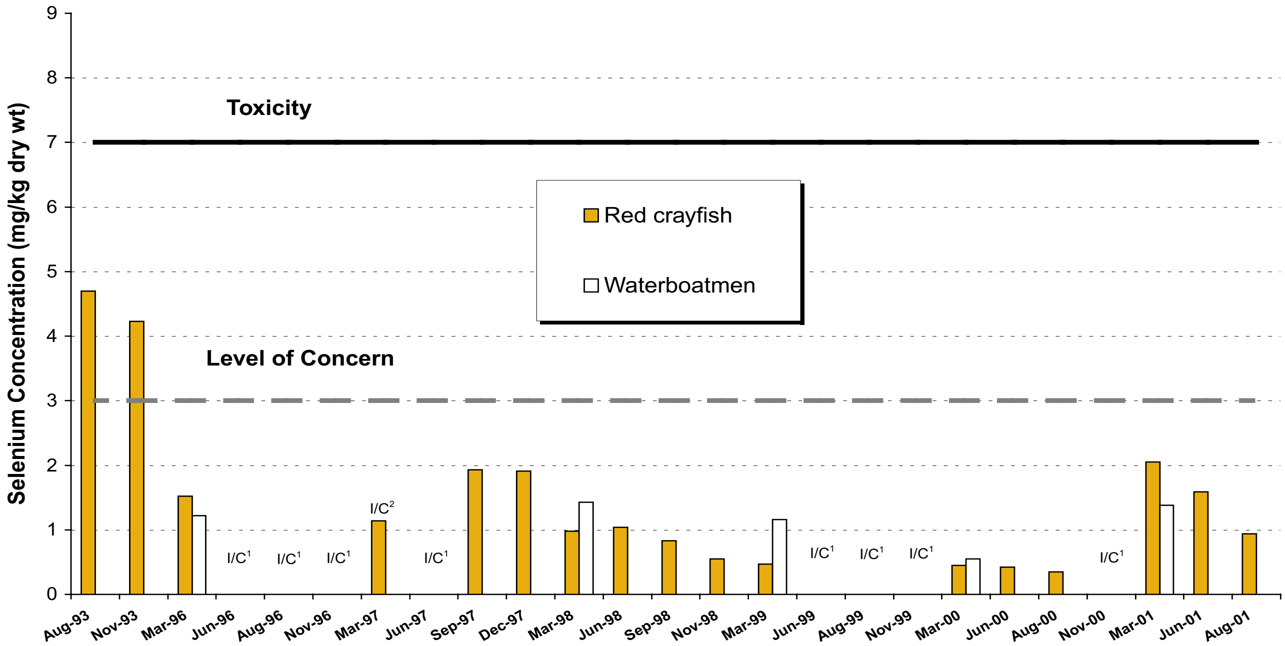
San Joaquin River Below Mud Slough (Site H)

Site H is located at Hills Ferry on the San Joaquin River about two miles downstream of the Mud Slough confluence. This site represents the reach of the San Joaquin River most strongly influenced by agricultural drain water discharged by the GBP. One of the environmental commitments of the GBP is that it will not worsen water quality in the San Joaquin River. For practical reasons of year-round accessability, the site was located just upstream of the Merced River confluence; Merced River waters have relatively low concentrations of selenium. It is likely that many of the fish and invertebrates collected at Site H have moved into this area after foraging within the Merced River and other cleaner reaches of the San Joaquin River. Additionally, seasonally high flows in the Merced River can enter the San Joaquin River upstream of Site H, temporarily diluting the load of contaminants there. Due to these confounding influences on selenium body burdens, selenium concentrations in fish and invertebrate tissues collected at this site may not be well correlated with water concentrations of selenium at this site.

Fish (Whole-Body)

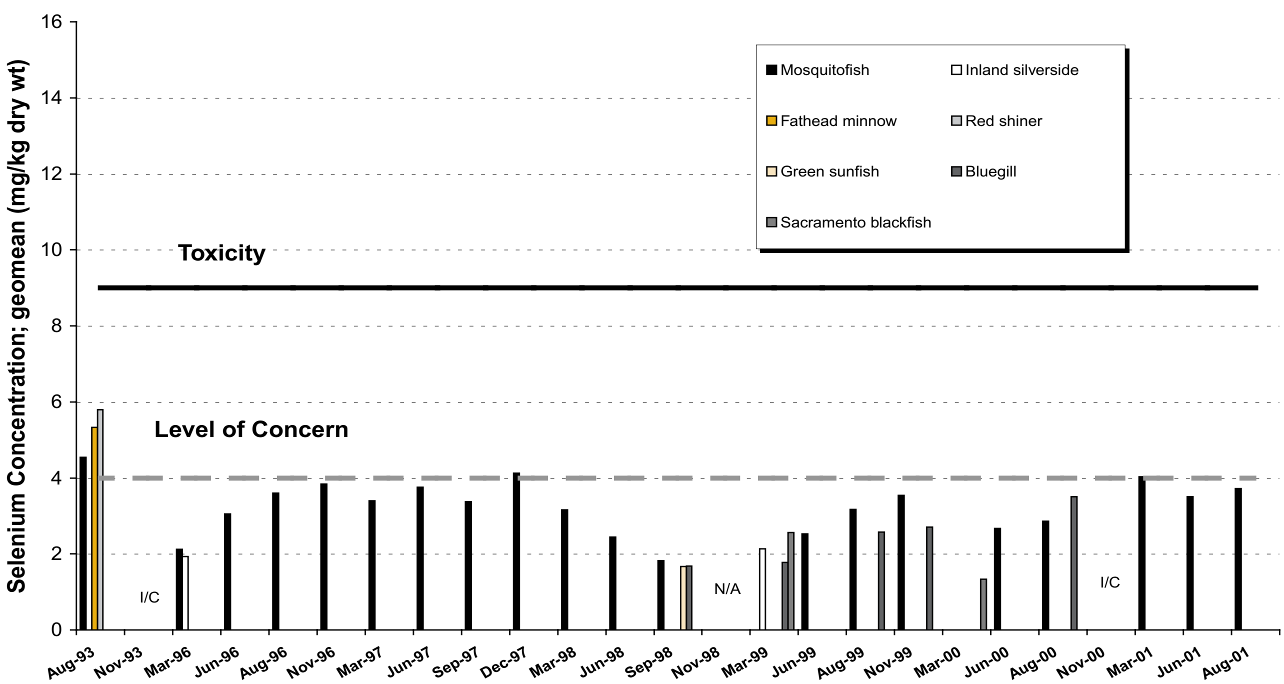
Selenium concentrations in nine composite samples of whole-body mosquitofish collected during WY 2001 averaged 3.8 mg/kg (dry weight), slightly below the 4 mg/kg (dry weight) threshold of Concern for warmwater fish (Figure 21). The average was greater than selenium concentrations in fish collected during WY 2000 (μ=2.9 mg/kg, n=16, $p<0.001$). Two composite samples collected in March 2001 exceeded the 4 mg/kg (dry weight) threshold of Concern. Despite this, selenium concentrations in composite whole-body fish samples throughout the five years of GBP operation have generally remained below the 4 mg/kg (dry weight) threshold of Concern and are not significantly different than concentrations in fish collected before the GBP began in 1996 (μ=3.78, n=21, $p<0.925$).

Figure 20. Selenium Concentration in Invertebrates from the San Joaquin River Upstream of the Mud Slough Confluence (Site G).



I/C[1]: Insufficient Catch of Red Crayfish for Adequate Quarterly Sample
I/C[2]: Insufficient Catch of Waterboatmen for Adequate Annual Sample

Figure 21. Selenium Concentrations in Whole-Body Fish Tissue from the San Joaquin River Downstream of the Mud Slough Confluence (Site H).



I/C: Insufficient Catch of Targeted Fish Species for Adequate Sample
N/A: No Analysis of Collected Samples

Invertebrates

Selenium concentrations in three composite samples of red crayfish collected from this site in WY 2001 ranged from 3.3 mg/kg to 3.5 mg/kg (dry weight), with an average of 3.4 mg/kg, which is above the 3 mg/kg (dry weight) threshold of Concern associated with known adverse effects on higher order consumers (Figure 22). The average selenium concentration in two composite samples of waterboatmen collected in WY 2001 was 1.38 mg/kg (dry weight), which was not significantly higher than the average selenium concentration of waterboatmen collected in WY 2000 (μ=0.6 mg/kg dry weight, n=3, p=0.06). The selenium concentration in all three invertebrate samples caught at this site in March 2001 exceeded the threshold of Concern of 3 mg/kg (dry weight). This was the first time such levels have been measured since monitoring began here in 1993.

Fish Communities Assessment

Fish communities assessment was conducted to describe fish assemblages based on species richness, abundance and community structure. Fish populations were sampled in Mud Slough at Highway 140 (Site E), San Joaquin River at Fremont Ford (Site G), and San Joaquin River below Mud Slough (Site H). Fish assemblages from these sites were compared both spatially and temporally to see if conditions for fish species in the San Joaquin River improved and conditions in Mud Slough degraded. We sampled in August and November 1993 and March, June, and August/September of the years 1996 - 2001. As the Grassland Bypass Project began operation in September 1996, this sampling schedule provided a before-and-after picture of the fish communities at these sites. Only data collected with standardized sampling methodologies and effort were analyzed.

Table 3 is a compilation of the 31 fish species (n=18,946) that have been collected at these sites during 5 pre-project and 16 post-project sampling events. Native fish represented 2% of the catch by number (n=423) and 27% of the catch by species.

Only four native species were caught during the 2001 WY at the three sites. One splittail, one Sacramento sucker, and two Sacramento blackfish were collected at the Site G in March 2001. No Chinook salmon were caught this year at either site. Annual spring abundance of fry and survival of juvenile chinook salmon in the delta appear to be influenced by river flow rate and temperature; survival and abundance decreased as flow rates decreased and temperatures increased (Kjelson, Raquel, and Fisher 1982 and Brandes and McLain 2000).

Sacramento blackfish continue to be the most abundant native fish throughout the study. The most common non-native fish are mosquitofish, inland silversides, fathead minnow, and carp.

We ran simple linear regression on trophic types caught at each site during the period 1993 to 2001. Invertivores and omnivores were dominant at all three sites and had complementary distributions. No time trend is evident in invertivores and omnivores at Site E (Figure 23). There appears to be an increase in invertivores and a decrease in omnivores caught at Site G (Figure 24). There appears to be a slight decrease in invertivores and an increase in omnivores at Site H (Figure 25).

Based on linear regression, there appears to be a slight decrease in the total anomalies observed at Sites E and H for the various groups of fishes at each site (Figure 26).

During September and October 1997, about one year after implementation of the GBP, Saiki (1998) sampled fish at 13 sites in the Grassland area. These sites correspond to locations he had surveyed more than a decade earlier (Saiki 1986). Some of his sample sites were the same as, or close to, GBP monitoring sites, but others were located in areas not monitored by the GBP. The SLD was the only site in the area that lacked bluegill and goldfish, and overall, fewer species of fish were found in the SLD than at any other site. However, Saiki did not find any significant difference in community structure related to the proportion of drainwater present. To explain this, he noted that all waterways in the area are overwhelmingly dominated by introduced species having broad environmental tolerances. Saiki's findings are consistent with those of the GBP biological monitoring program.

After 5 years of Project operation, current methods of assessing fish species assemblages cannot distinguish any significant temporal or geographic pattern of variation in fish community structure attributable to the Project.

Assessment of Risk to Public Health from Consumption of Fish

During the fifth year of project operation, selenium concentrations in all carp fillets from Site E ranged from 0.9 to 1.9 mg/kg (wet weight, n=9), below the 2 mg/kg health screening level (Figure 27).

Selenium concentrations in carp fillets collected at Sites G (μ=0.5 mg/kg wet weight, n=60) and H (μ=0.7 mg/kg wet wt, n=57) on the San Joaquin River were well below the 2 mg/kg health screening level and have remained this level throughout all five years of GBP operations (Figures 28 and 29).

Table 3. Fishes collected from Grassland Bypass Project Stations E, G, and H in decreasing order of numerical abundance.

Species	Number	Origin	Trophic Classification	Tolerance
Mosquitofish, *Gambusia affinis*	7,139	Introduced	I	T
Inland silverside, *Menidia beryllina*	3,311	Introduced	I	M
Fathead minnow, *Pimephales promelas*	2,058	Introduced	O	T
Carp, *Cyprinus carpio*	1,873	Introduced	O	T
Red shiner, *Cyprinella lutrensis*	816	Introduced	O	T
White catfish, *Ameiurus catus*	806	Introduced	I/P	T
Bluegill, *Lepomis macrochirus*	626	Introduced	I	T
Goldfish, *Carassius auratus*	346	Introduced	O	T
Largemouth bass, *Micropterus salmoides*	318	Introduced	P	T
Threadfin shad, *Dorosama petenese*	303	Introduced	I	M
Green sunfish, *Lepomis cyanellus*	250	Introduced	I/P	T
Redear sunfish, *Lepomis microlophus*	233	Introduced	I	M
Sacramento blackfish, *Orthodon microlepidotus*	211	Native	O	T
Channel catfish, *Ictalurus punctatus*	197	Introduced	I/P	M
Splittail, *Pogonichthys macrolepidotus*	109	Native	O	M
Bigscale logperch, *Percina macrolepida*	77	Introduced	I	T
Black crappie, *Pomoxis nigromaculatus*	53	Introduced	I/P	M
Sacramento sucker, *Catostomus occidentalis*	26	Native	O	M
Prickly sculpin, *Cottus asper*	25	Native	I	M
Striped bass, *Morone saxatilis*	25	Introduced	P	M
Spotted bass, *Micropterus punctulatus*	24	Introduced	P	M
Sacramento pikeminnow, *Ptychocheilus* grandis	22	Native	I/P	M
Brown bullhead, *Ameiurus nebulosus*	21	Introduced	I/P	T
Chinook salmon, *Oncorhynchus tshawytscha*	21	Native	I	I
Smallmouth bass, *Micropterus* dolomieui	19	Introduced	I/P	M
American shad, *Alosa sapidissima*	9	Introduced	I	M
Black bullhead, *Ameiurus melas*	8	Introduced	I/P	T
White crappie, *Pomoxis annularis*	8	Introduced	I/P	T
Hitch, *Lavinia exilicauda*	4	Native	O	M
Tule perch, *Hysteocarpus traski*	4	Native	I	I
Warmouth, *Lepomis gulosus*	2	Introduced	I	M
Golden Shiner, *Notemigonus crysoleucas*	1	Introduced	I	M
Riffle sculpin, *Cottus gulosus*	1	Native	I	M

Totals		18,946	
Introduced	24 species	18,523	98%
Native	9 species	423	2%

Trophic Classification: O=Omnivore, I=Invertivore, P=Piscivore, I/P=Invertivore/Piscivore
Tolerance to environmental degradation: I=Intolerant, M=Moderately Tolerant, T=Tolerant

Figure 22. Selenium Concentration in Invertebrates from the San Joaquin River Downstream of the Mud Slough Confluence (Site H).

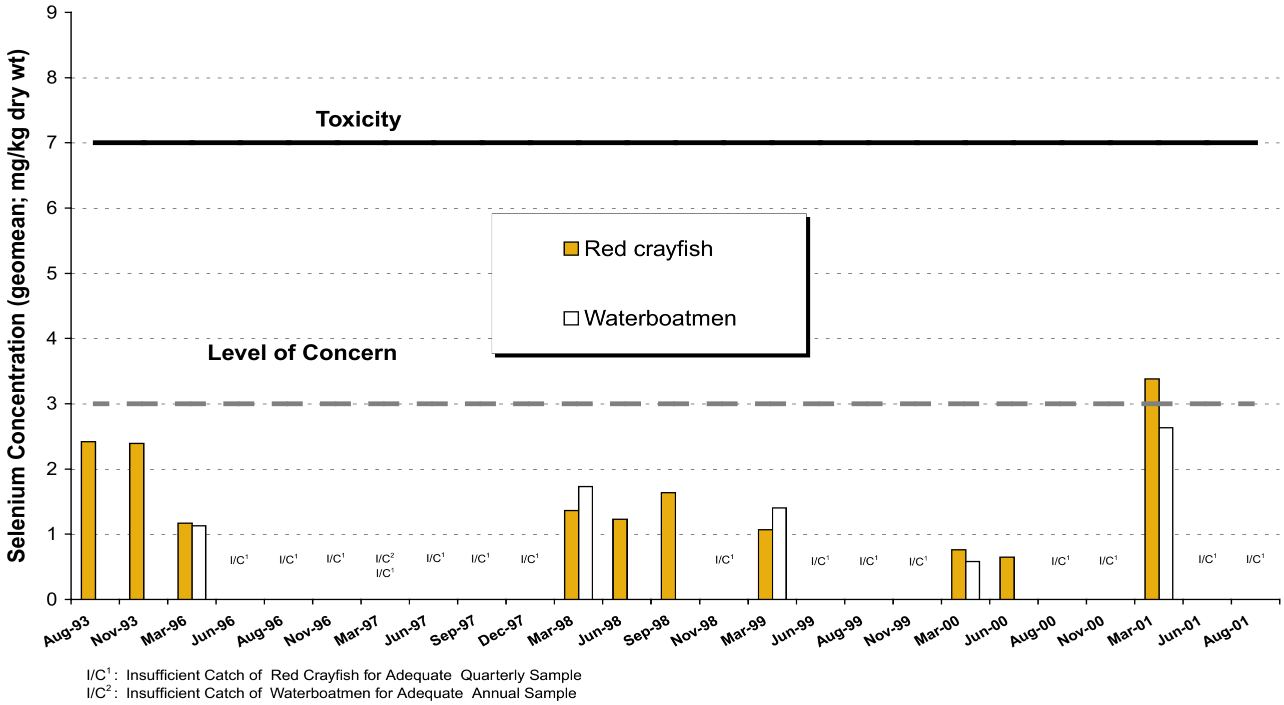


Figure 23. Percent abundance of trophic classifications over time at Site E.

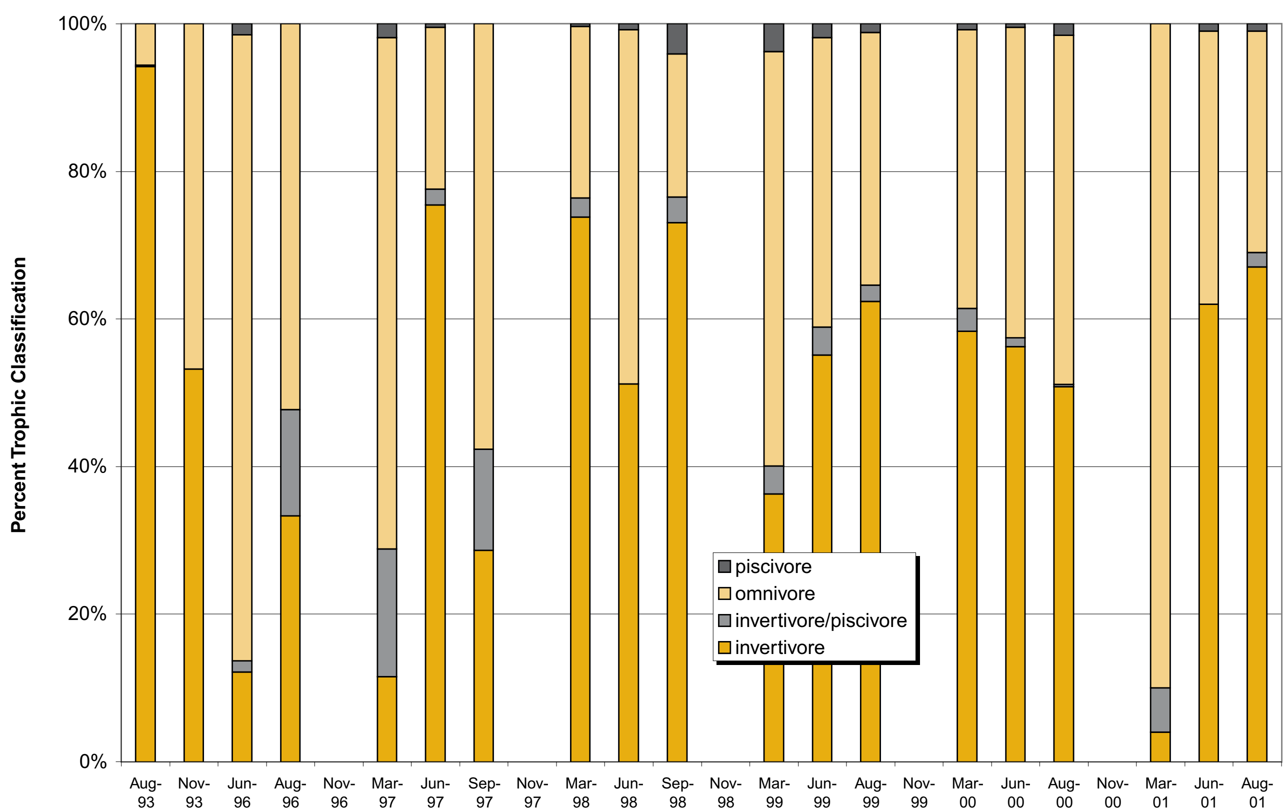


Figure 24. Percent abundance of trophic classifications over time at Site G.

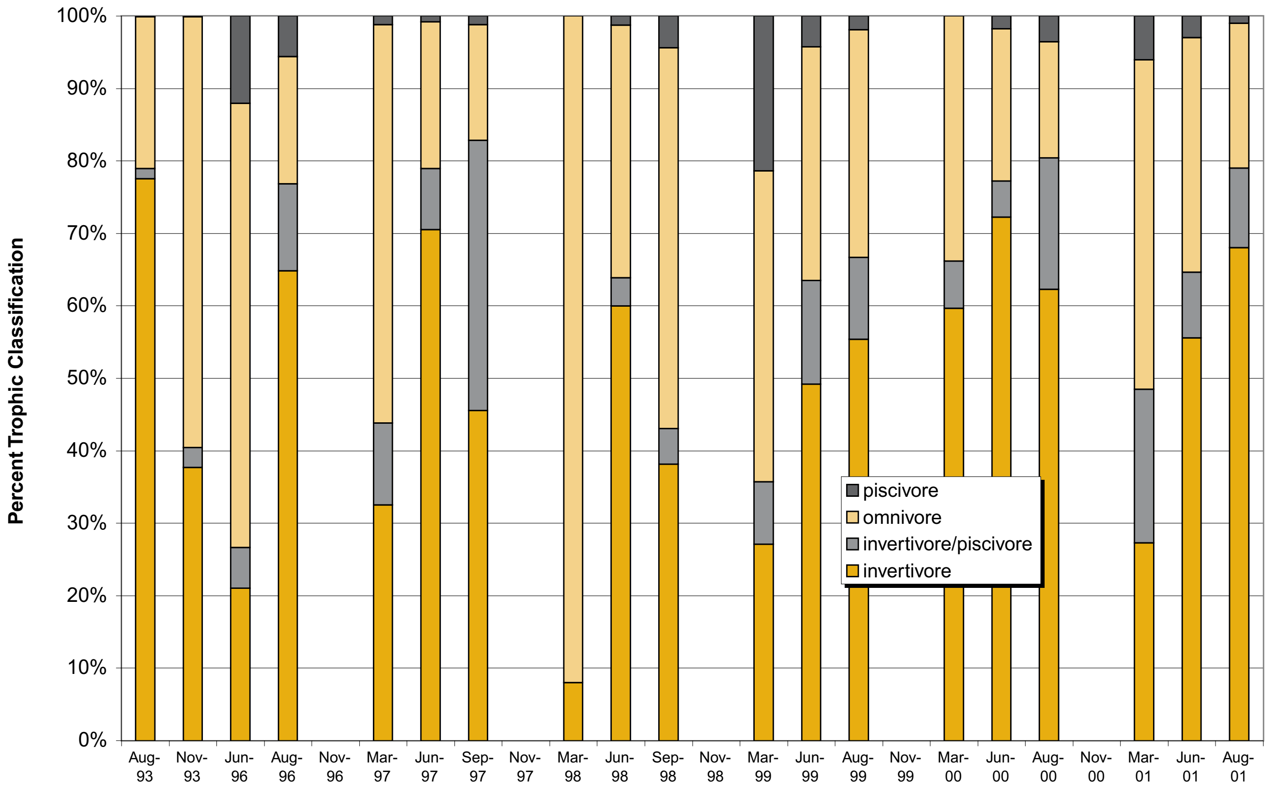


Figure 25. Percent abundance of trophic classifications over time at Site H.

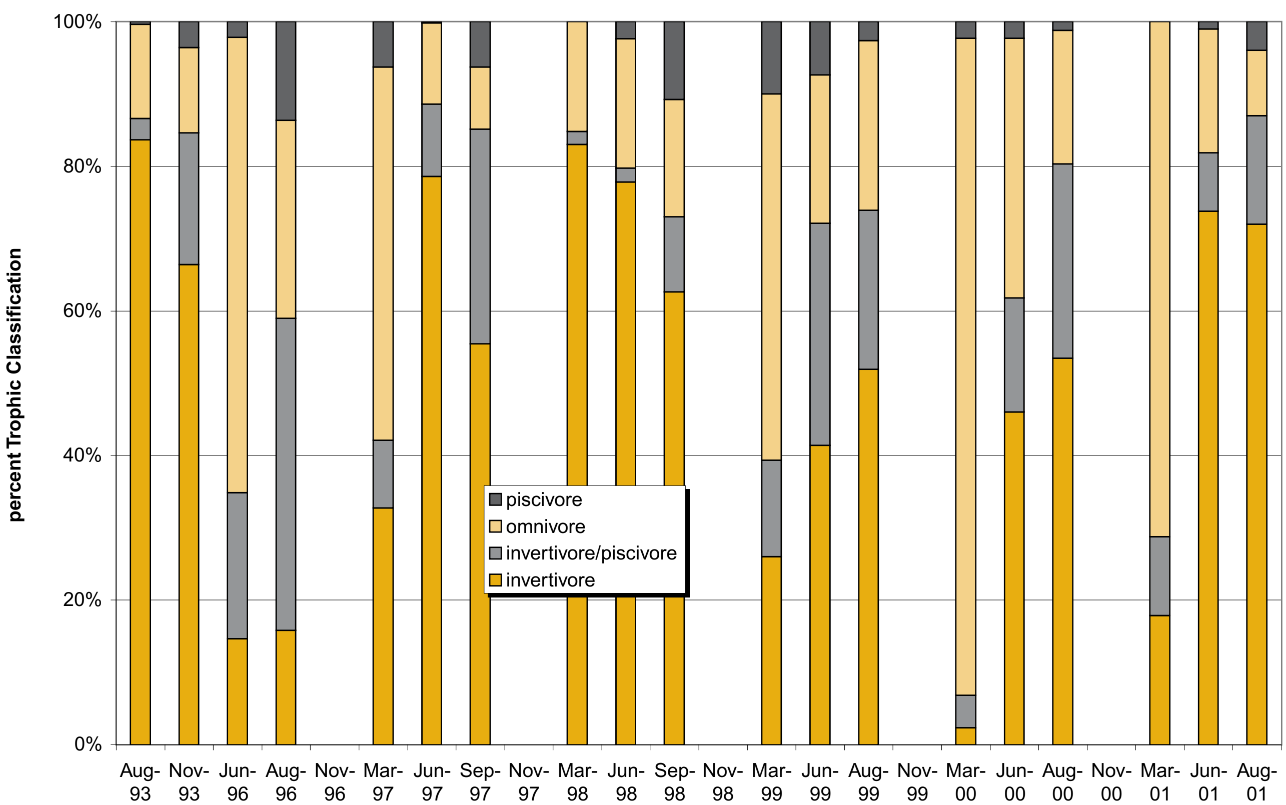
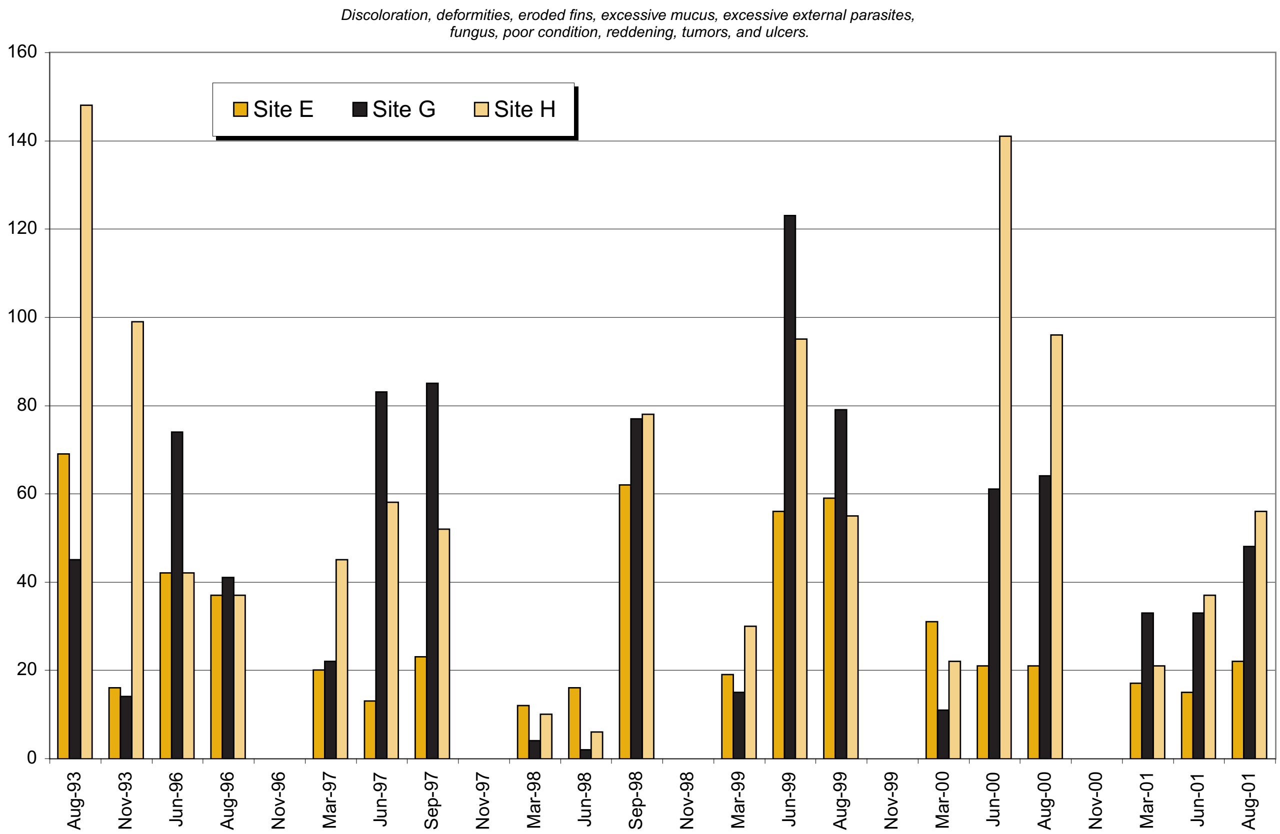


Figure 26. Total Anomalies in all Fish Species Caught from Sites E, G, and H.



Selenium in Plants

Composite samples of plant material that provides preferred forage for waterfowl (seed heads) have been collected in late summer for several years, but funding has been adequate to analyze some of these materials for selenium in the last two years (Figure 30). In WY 2001, the highest selenium concentrations found in water-side plants were from samples collected along Mud Slough downstream of the San Luis Drain (Sites D and I2). All samples were well below the threshold of Concern for reproductive effects on waterfowl due to dietary exposure (3 mg/kg) except a composite sample of swamp timothy seed heads (3.5 mg/kg) collected from the banks of Mud Slough below the San Luis Drain outfall (Site D). These data suggest that birds in this area are generally at greater risk due to eating invertebrates and fish than from eating plants.

The concentrations of selenium in knotgrass (*Paspalum disthum*) seed heads collected by CDFG at Sites E, G, and H were well below the 3 mg/kg (dry weight) threshold of Concern. The average concentration of selenium in three composite samples of seeds collected at Site E was 1.94 mg/kg (dry weight) during WY 2001. This average was greater than the average of seed samples collected during WY 2000 (μ=0.9, n=3,p<0.150) and before the GBP (μ=0.3, n=3, p<0.071). The average concentration of selenium in composite samples of seed collected at Sites G and H were 0.19 mg/kg (dry weight) and 0.26 mg/kg (dry weight), respectively. These averages were not significantly different than the average selenium concentration of seeds collected before the GBP (p<0.184 and p<0.543, respectively).

Selenium in Bird Eggs

A single egg was randomly collected and analyzed from each of 23 bird nests in the Grassland area in 2001 (Figure 31). Species sampled included killdeer, black-necked stilt, gadwall, wood duck, cinnamon teal, kestrel, barn swallow, black phoebe and Redwing blackbird. The selenium concentrations in all eggs collected in the Salt Slough area (San Luis Unit) were within the "No-Effect" range of concentrations (<6 mg/kg). Selenium concentrations in eggs analyzed from the Mud Slough area (geometric mean 4.5 mg/kg, n=10) were significantly (p=0.02, t-test performed on log-transformed concentrations) higher than those analyzed from the Salt Slough area (geometric mean 1.9 mg/kg, n=13). One Mud Slough area egg (black phoebe: 7.0 mg/kg) was in the Concern

Table 4. Aquatic Hazard Assessment of Selenium in Mud and Salt Slough Areas.

	BEFORE PROJECT 1995-Sept. 1996		SINCE PROJECT WY1997		WY1998		WY1999		WY2000		WY2001	
	concentration	hazard	concentration	hazard	concentration	hazard	concentration	hazard	concentration	hazard	concentration	hazard
Mud Slough below Drain outfall												
Water	19.4 µg/l	high	79.6 µg/l	high	104.0 µg/l	high	50.7 µg/l	high	66.0 µg/l	high	50.8 µg/l	high
Sediment	0.4 µg/g	none	0.76 µg/g	none	2.0 µg/g	low	4.8 µg/g	high	4.4 µg/g	high	3.5 µg/g	moderate
Invertebrates	1.6 µg/g	none	3.3 µg/g	low	11 µg/g	high	7.0 µg/g	high	15.3 µg/g	high	7.1 µg/g	high
Fish eggs	14.2 µg/g	moderate	56.1 µg/g	high	34.2 µg/g	high	39.6 µg/g	high	46.5 µg/g	high	54.8 µg/g	high
Bird eggs	3.12 µg/g	minimal	4.4 µg/g	minimal	6.6 µg/g	low	10 µg/g	low	5.1 µg/g	low	7.0 µg/g	low
TOTAL SCORE	13	moderate	16	high	21	high	23	high	23	high	22	high
Salt Slough												
Water	37.8 µg/l	high	3.4 µg/l	moderate	5.1 µg/l	high	1.5 µg/l	minimal	1.7 µg/l	minimal	2.1 µg/l	low
Sediment	0.8 µg/g	none	0.94 µg/g	none	2.1 µg/g	low	0.93 µg/g	none	0.68 µg/g	none	0.77 µg/g	none
Invertebrates	4.7 µg/g	moderate	2.6 µg/g	minimal	3.15 µg/g	low	2.8 µg/g	minimal	2.7 µg/g	minimal	0.7 µg/g	minimal
Fish eggs	28.1 µg/g	high	17.8 µg/g	moderate	12.9 µg/g	moderate	11.2 µg/g	moderate	14.5 µg/g	moderate	12.5 µg/g	moderate
Bird eggs	5.2 µg/g	low	3.6 µg/g	minimal	3.72 µg/g	minimal	2.7 µg/g	none	4.9 µg/g	minimal	4.0 µg/g	minimal
TOTAL SCORE	**18**	**high**	**13**	**moderate**	**17**	**high**	**10**	**low**	**11**	**low**	**12**	**moderate**

Notes:
Hazard scale for components (water, sediment, etc.): none (no hazard),1; minimal, 2; low, 3; moderate, 4; high 5.
Hazard scale for total score (sum of component scores): none, 5; minimal 6-8; low, 9-11; moderate, 12-15; high, 16-25.

range (6-10 mg/kg) and two Mud Slough area eggs (killdeer: 15.6 and 26.3 mg/kg) were above the Toxicity threshold (10 mg/kg).

Aquatic Hazard Assessment of Selenium

To provide an estimate of ecosystem-level effects of selenium, Lemly (1995, 1996) developed an aquatic hazard assessment procedure that sums the effects of selenium on various ecosystem components to yield a single characterization of overall hazard to aquatic life. Lemly's procedure applied to Mud Slough downstream of the SLD outfall indicated that the hazard to aquatic life in the affected portion of Mud Slough continued to be "high" in WY 2001 (Table 3). In the Salt Slough area, the Lemly index rose from "low" in WY 2000 to "moderate" in WY 2001 (Table 3) due to a small increase in the maximum concentration of selenium measured in water (1.7 µg/L on 15 March 2000; 2.1 µg/L on 1 March 2001). Because the Lemly index is based on maximum concentrations, it is highly sensitive to data "outliers." A Lemly index was not determined for San Joaquin River sites due to lack of sufficient sample of invertebrates and because bird eggs, one component of the index, were not sampled there.

Boron in Plants

Samples of seed heads from plants (knotgrass, smartweed, swamp timothy, bullrush sedge) collected in August 2001 from Sites C, D, E, I2, F, G, and H were analyzed for boron.

At Site C, two of three samples (23.2, 57.2, and 115.0 mg/kg) exceeded the threshold of Concern for boron in plants as diet (30 mg/kg, Table 2). At Sites D and I2 all samples exceeded the threshold of Concern (Site D: 58.2, 48.6, and 152 mg/kg; Site I2: 50.1 and 57.9 mg/kg). At Site F, all samples (20.9, 28.9, and 19.6 mg/kg) were in the No-Effect zone.

The average concentration of boron in knotgrass (*Paspalum distichum*) seed heads in three composite samples collected by CDFG at Site E was 48 mg/kg (dry weight). This was above the 30 mg/kg (dry weight) level of Concern. The average concentration of boron in knotgrass seed heads collected at Sites G (µ=8.3, n=3) and H (µ=13.7, n=3) were well below the level of Concern.

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Figure 27. Se Concentration in Fish Muscle Tissue from Mud Slough at Hwy 140 (Site E).

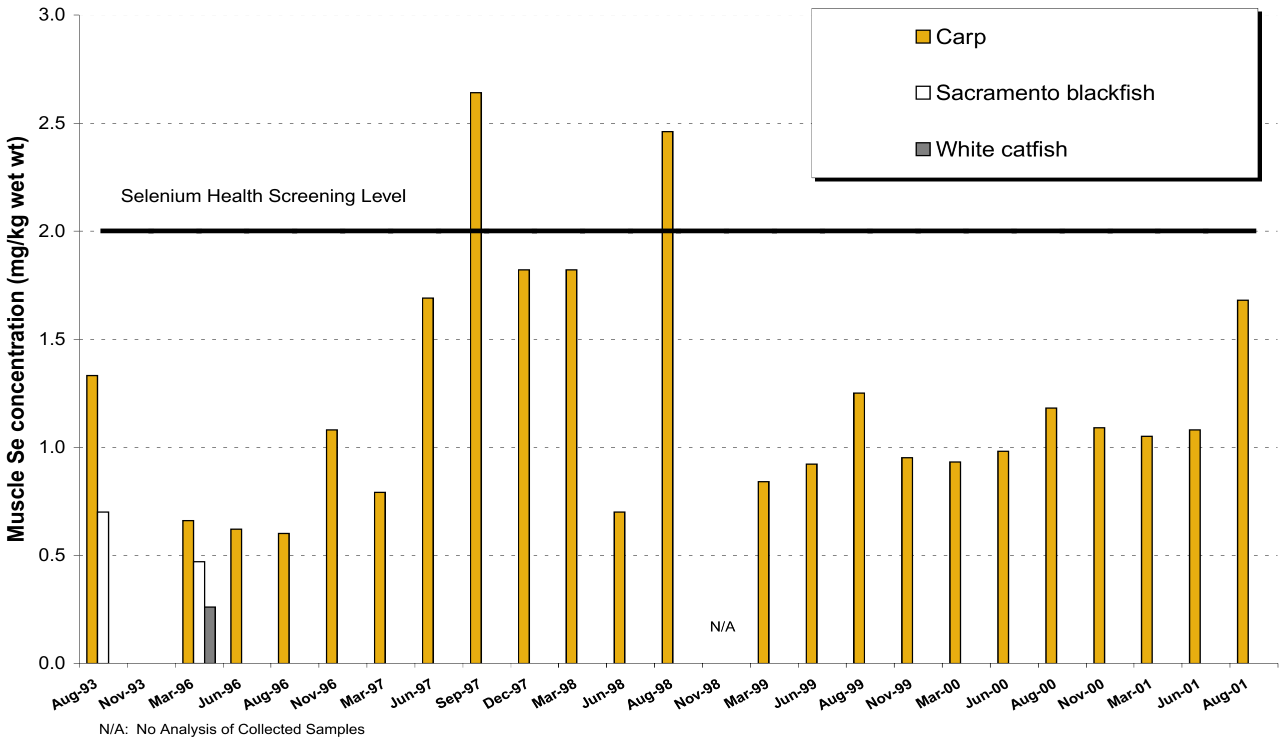


Figure 28. Se Concentration in Fish Muscle Tissue from the San Joaquin River Upstream of the Mud Slough Confluence (Site G).

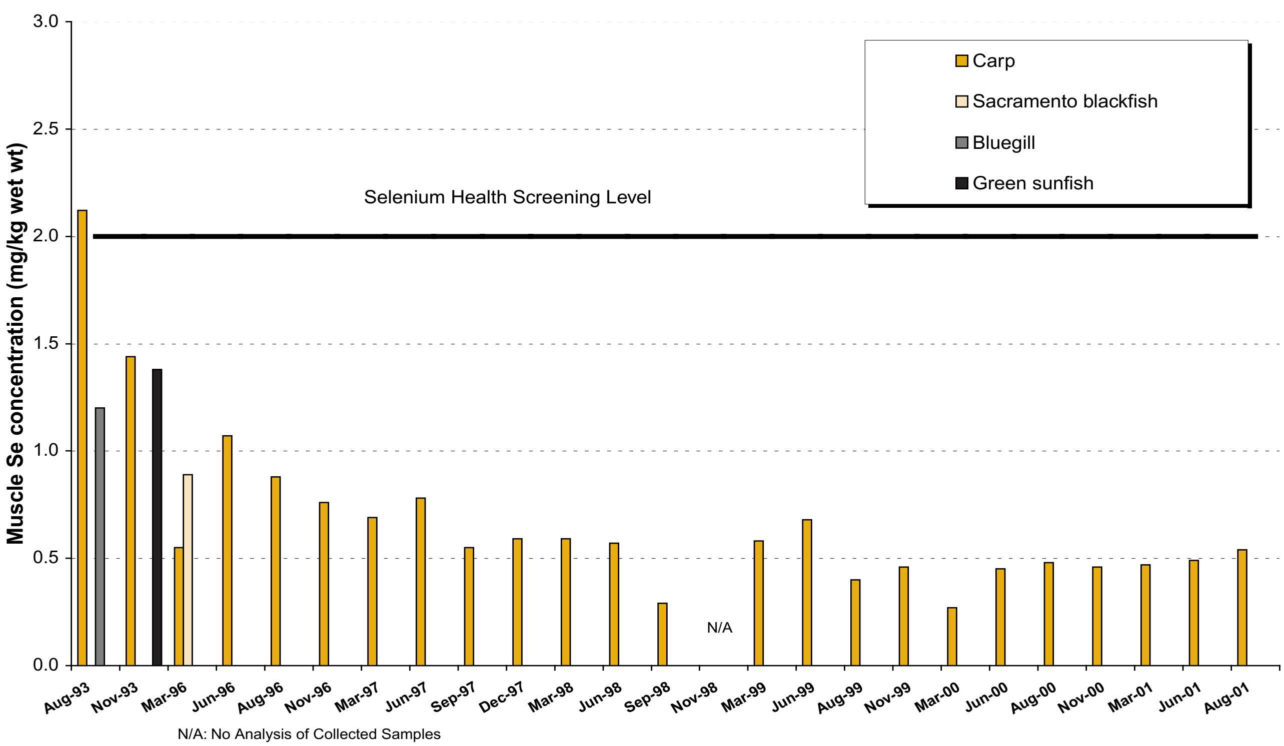
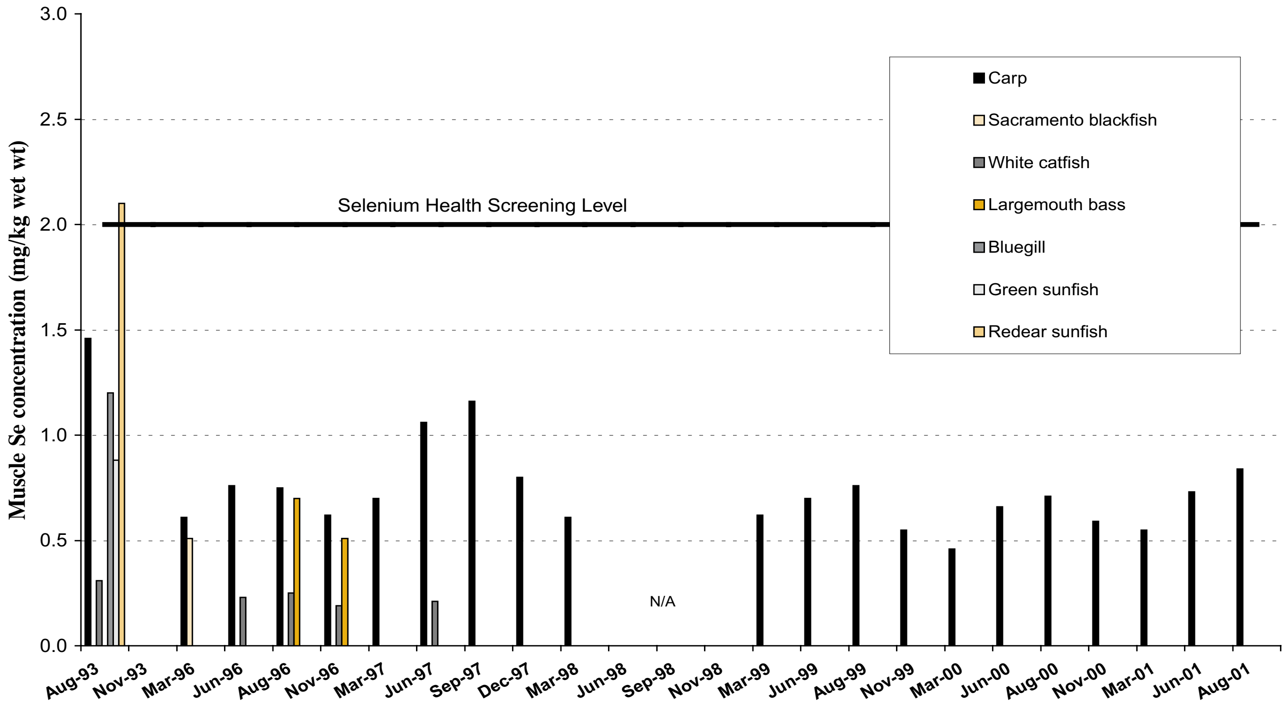


Figure 29. Selenium Concentration in Fish Muscle Tissue from the San Joaquin River Downstream of the Mud Slough Confluence (Site H).



N/A: No Analysis of Collected Samples

Figure 30. Selenium in plants (seed heads where applicable).

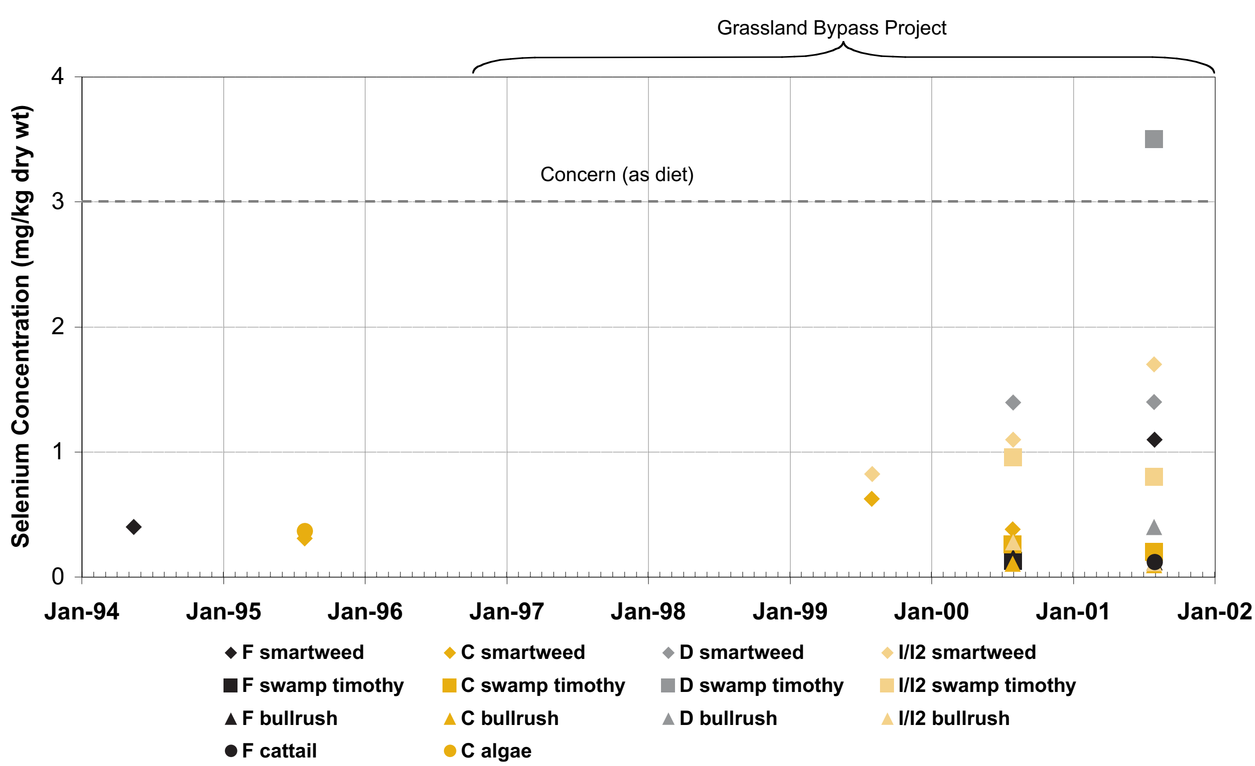
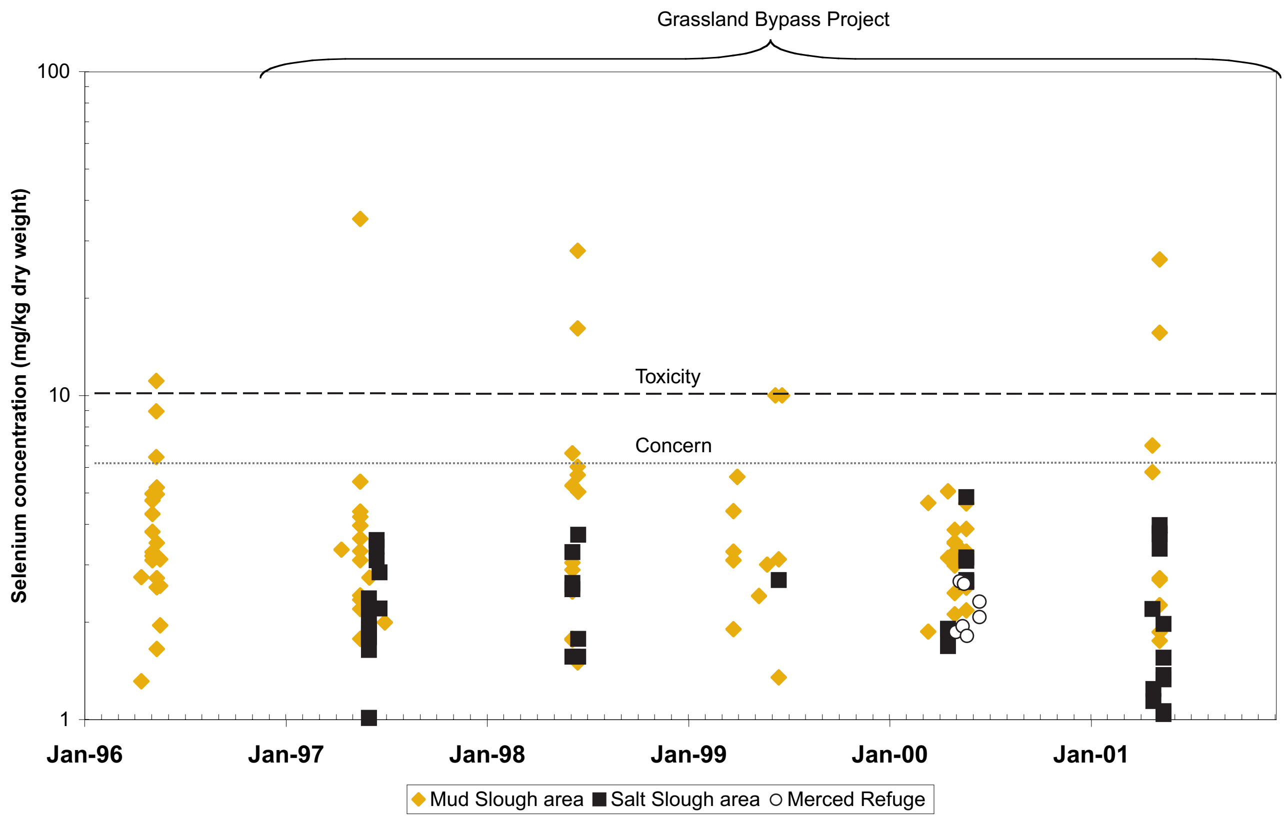


Figure 31. Selenium in bird eggs.



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GRASSLAND BYPASS PROJECT

8

Toxicity Testing for the Grassland Bypass Project

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Introduction

The objective of the laboratory toxicity-testing program is to evaluate the potential toxicity of waterborne contaminants within the GBP area using standardized bioassay protocols conducted under controlled environmental conditions. The laboratory toxicity tests evaluate one species within each of three trophic levels using short-term chronic testing procedures (7 or 4 days) and lethal (survival) and non-lethal (growth or reproduction) endpoints (USEPA 1987; 1994). The test species are *Selenastrum capricornutum* (alga), *Daphnia magna* (water flea), and *Pimephales promelas* (fathead minnow).

The testing is not specific for any single chemical exposure, but rather demonstrates the net effect of only waterborne contaminant exposures in the site waters on the selected test species. During toxicity testing, test species are fed a controlled diet that is unrelated to field sources of food. For this reason, toxicity testing is not expected to detect selenium toxicity in invertebrates and fish because the main route of exposure in these groups of organisms is through the food they eat. However, selenium toxicity in algae is through direct exposure from water and thus toxicity testing may detect selenium toxicity in algae.

Tests are conducted at the screening level, comparing the ambient water to 100% test water. If significant toxicity is observed, definitive tests (dilution series) may be conducted. Water samples are collected from Stations B, C, D, and F for each monthly testing period. The Delta Mendota Canal station is the control site. *In-situ* chronic toxicity testing using caged fathead minnows has been eliminated during the course of the program, as has measurement of selenium bioaccumulation in algae.

The toxicity program is conducted by Block Environmental Service's (BES) Bioassay Laboratory Division under contract with the San Luis & Delta-Mendota Water Authority. The U. S. Environmental Protection Agency (USEPA) provides technical assistance and program oversight. The toxicity program is carried out monthly.

WY 2001 represents the 5th and final year (Phase I) of the monitoring program. The Phase II monitoring program started on October 1, 2001 and continues through December 31, 2009. WY 2001 monthly data are presented in this chapter and are compared graphically with the previous 4 years.

Materials and Methods

Three species are used for 5 toxicity tests using the short-term chronic testing procedures (USEPA, 1987; 1994). The test species are the freshwater alga (*Selenastrum capricornutum*), the fathead minnow (*Pimephales promelas*), and the daphnid invertebrate *(Daphnia magna)*. The 5 specific tests are 1. fathead minnow survival, 2. fathead minnow growth, 3. Daphnia magna survival, 4. Daphnia magna reproduction, and 5. freshwater algal growth. Grab samples are collected from Sites B, C, D, F, and the DMC each month. The toxicity tests uses 3 water samples (grab sample) collected on Day 0, Day 3, and Day 5 of the 7-day testing period. Each test is performed using 100% water from the 4 sites and compared to 100% water from the DMC. All toxicity test results are analyzed using the software program Toxicity Information Management System (TOXIS, Version 2. 5, EcoAnalysis, Inc.). TOXIS determines if there is a statistically significant reduction ($p<0.05$) between each of the 4 sites to the ambient DMC waters each month.

In order to assess independently the health of the test organisms and laboratory performance, a concurrent reference toxicant test is conducted for each of the test species during the monthly testing periods. The reference toxicant test is conducted using a dilution series of the toxicant in laboratory control water. The toxicity endpoints from the reference toxicant tests of each test method are plotted on a running control chart of the last 20 tests. The mean and upper and lower control limits (± 2 standard deviations) are recalculated with each successive test result. The outliers, which are values falling outside the upper and lower control limits, and trends of increasing or decreasing sensitivity, are identified. At the p= 0.05 probability level, 1 in 20 tests (5%) would be expected to fall outside of the control limits by chance alone.

Water samples for chemical analysis are collected during each sampling event. Selenium and sulfate parameters are analyzed by the U. S. Bureau of Reclamation's (USBR) contract laboratories. Other laboratory analyses (performed by BES) are temperature, dissolved oxygen (DO), pH, conductivity, salinity, ammonia, total chlorine, hardness, alkalinity, and total suspended solids. Field analyses are also made for DO, pH, conductivity and salinity during collection of the first of the three samples collected.

Sampling and testing protocols for each procedure are found in the Compliance Monitoring Program for Use and Operation of the Grassland Bypass Project

Figure 1
Site B Compared to Delta Mendota Canal—Chronic Endpoints

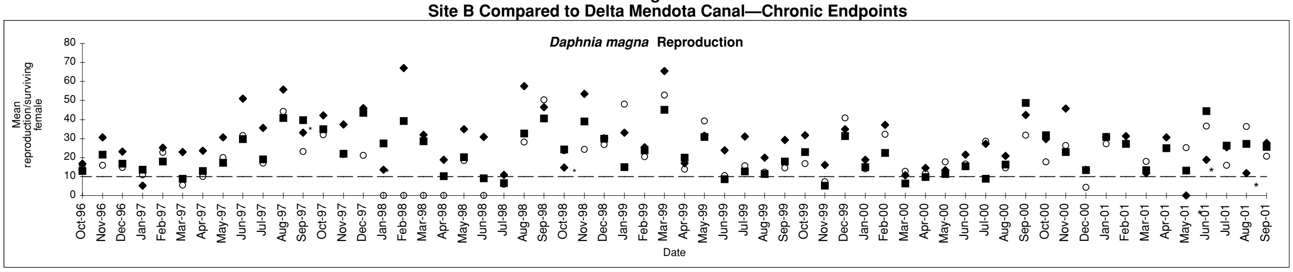


Figure 2
Site B Compared to Delta Mendota Canal—Chronic Endpoints

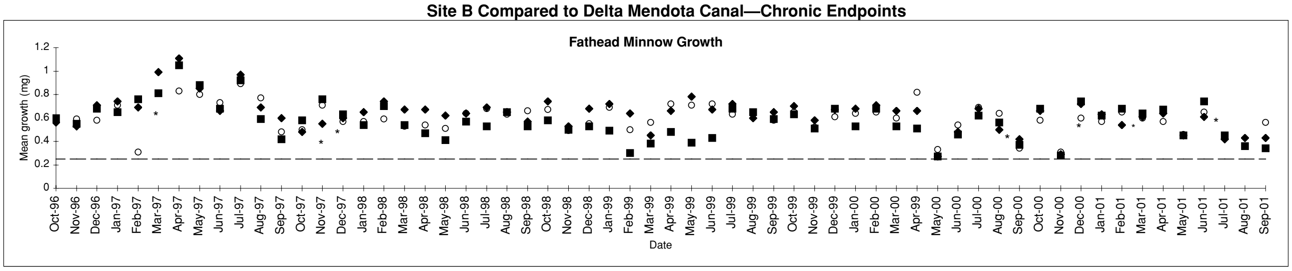


Figure 3
Site B Compared to Delta Mendota Canal—Chronic Endpoints

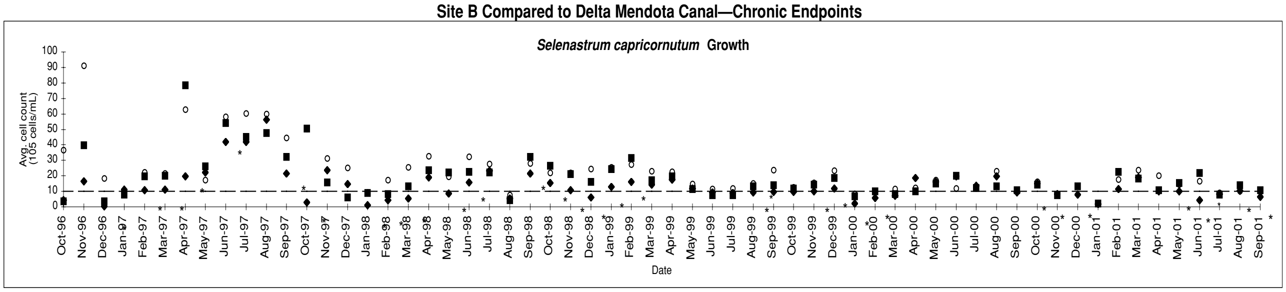


Figure 4
Site B Compared to Delta Mendota Canal—Acute Endpoints

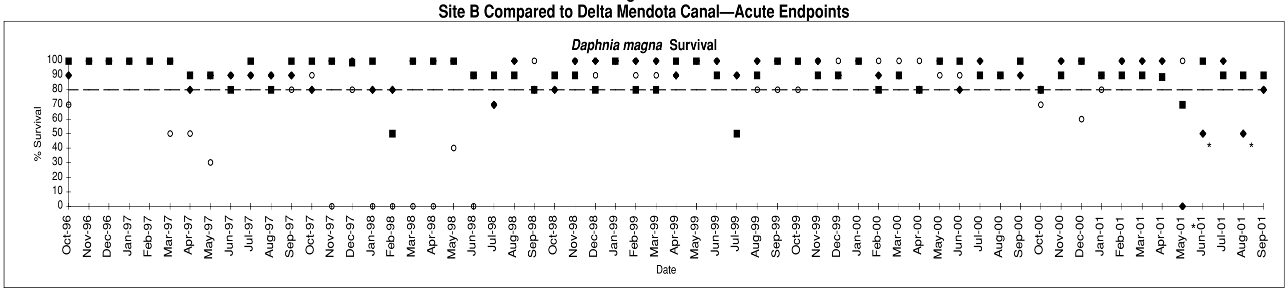
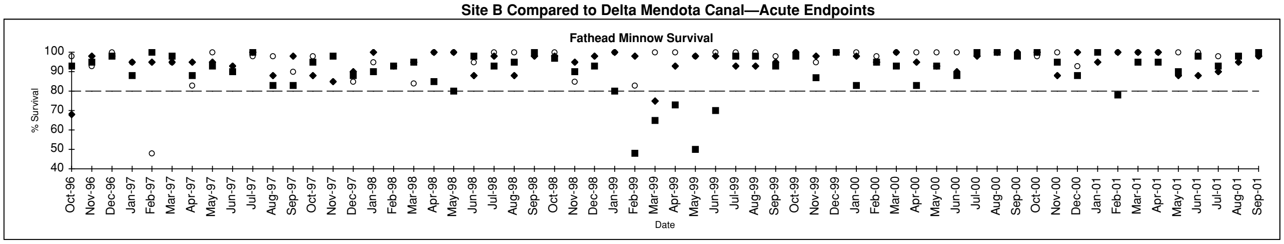


Figure 5
Site B Compared to Delta Mendota Canal—Acute Endpoints



■ Delta Mendota Canal (control)
◆ Site B
* Results statistically different from control
❍ Laboratory Control
-- Minimum test acceptability for control

(USBR et al. , 1996) and the Quality Assurance Project Plan (Entrix, Inc. , 1997).

Results

Toxicity testing, as described in the Compliance Monitoring Program for Use and Operation of the Grassland Bypass Project (USBR et al. , 1996) began in October 1996. Data for the 4 previous years may be found in the Annual Reports (USBR, 1998, 1999, 2000 and 2001). Toxicity results from the 5th year are presented in Tables 1 through 5. Figures 1 through 20 graphically present information for all 5 years.

Water chemistry data measured in the field are presented in Tables 6 through 9. Table 10 provides information on the sample collection depth. Tables 12-15 depict the statistical occurrences from all of the tests over the 5-year period. Laboratory water quality data are presented in Tables 16 through 27. Water quality data comparing each of the stations are found in Figures 21–30.

Laboratory Toxicity Testing

There were 12 monthly laboratory toxicity tests between October 2000 and September 2001.

Daphnia magna Short-Term Chronic Survival

The D. magna toxicity test survival results are presented in Table 1 and in Figures 4, 9, 14, and 19 (Tables and Figures are not sequential since data are

Table 1
***Daphnia magna* Survival (Percent)**

DATE	SITE LOCATION					
	B	C	D	F	Ambient (DMC)	Laboratory Control
Oct-00	80	80	60 *	80	80	70 **
Nov-00	100	100	100	100	90	100
Dec-00	80	80	80	100	100	60 **
Jan-01	90	70 *	100	100	90	80
Feb-01	100	100	90	100	90	100
Mar-01	100	100	90	90	90	90
Apr-01	100	100	100	100	89	89
May-01	0*	100	100	100	70**	100
Jun-01	50 *	70 *	70 *	90	100	100
Jul-01	100	100	60 *	80	90	90
Aug-01	50 *	100	30 *	100	90	90
Sep-01	80	100	90	100	90	80

* Statistically significant event (P=0.05). Statistics were computed between all site means and the DMC ambient water sample.

** DMC/Lab water failed to meet the survival (≥ 80%) acceptability criteria.

Table 2
***Daphnia magna* Mean Reproduction**
(Number of Neonates per Female + Standard Deviation)

DATE	SITE LOCATION					
	B	C	D	F	Ambient (DMC)	Laboratory Control
Oct-00	29.80 + 16.63	41.50 + 21.34	23.90 + 21.70	25.70 + 21.56	31.80 + 20.93	17.70 + 15.93
Nov-00	45.70 + 5.62	40.40 + 7.50	43.90 + 10.34	35.10 + 4.95	22.80 + 11.77	26.30 + 6.55
Dec-00	13.70 + 9.81	15.70 + 10.00	13.22 + 6.52	11.20 + 5.50	13.40 + 6.92	4.6 + 4.74 **
Jan-01	30.8 + 18.47	31.30 + 22.29	46.20 + 13.38	36.89 + 12.99	30.80 + 17.67	27.10 + 18.25
Feb-01	31.2 + 13.1	25.7 +8.4	25.1 + 12.02	29.9 +10.6	27.2 + 13.4	27.5 +10.4
Mar-01	11.70 + 3.56	21.90 + 9.89	19.30 + 9.02	15.60 + 8.15	13.40 + 6.28	17.80 + 9.99
Apr-01	30.70 + 12.27	28.60 + 7.82	36.50 + 12.45	26.20 + 9.07	24.89 + 13.46	24.78 + 12.08
May-01	0*	25.0 + 8.96	27.50 + 6.79	23.30 + 12.54	13.90 + 10.81	25.20 + 9.84
Jun-01	18.90 + 21.52 *	28.3 + 21.0*	27.6 + 19.16 *	47.90 + 19.72	44.50 + 11.05	36.40 + 8.36
Jul-01	25.33 + 4.58	28.50 + 5.58	16.80 + 14.76	17.70 + 12.27	26.20 + 11.70	15.90 + 9.79
Aug-01	11.7 + 28.3*	42.90 + 13.98	15.50 + 25.58 *	52.50 + 16.04	27.10 + 16.60	36.30 + 20.18
Sep-01	27.70 + 15.36	31.50 + 3.66	32.50 + 14.92	31.50 + 3.66	25.60 + 10.10	20.70 + 13.01

* Statistically significant event (P=0.05). Statistics were computed between all site means and the DMC ambient water sample.

** DMC/Lab Cl water failed to meet the reproduction (≥ 10) acceptability criteria.

presented by site designation and presented by species). Six months had statistically significant (p<0.05) reductions in survival of *D. magna* during the WY 2001: October (Site D), January (Site C), May (Site B), June (Sites B, C, and D), July (Site D) and August (Sites B and D), for a total of 9 tests.

All of the twelve concurrent *D. magna* reference toxicant survival endpoints for WY 2001 were within the control chart limitations.

The DMC ambient control data met the 80% minimum survival acceptability criterion for all sampling events except for May. Laboratory control met the survival acceptability criterion in all of the 12 sampling events except for December.

For the first 4 water years, *D. magna* survival results showed no significant reductions for survival for any of the stations, including the DMC ambient control.

Daphnia magna Short-Term Chronic Reproduction

The *D. magna* reproduction results are presented in Table 2 and in Figures 1, 6, 11, and 16. Three months showed statistically significant (p<0.05) reduced repro-

Table 3
***Pimephales promelas* (Fathead Minnow)**
Larval Survival (Percent + Standard Deviation)

DATE	SITE LOCATION B	C	D	F	Ambient (DMC)	Laboratory Control
Oct-00	100 + 0	75 + 0.27 *	93 + 0.10	100 + 0	100 + 0	98 + 0.05
Nov-00	88 + 0.13	15 + 0.10 *	23 + 0.15 *	63 + 0.17 *	95 + 0.06	100 + 0
Dec-00	100 + 0	63 + 0.13 *	73 + 0.17	88 + 0.15	88 + 0.19	93 + 0.15
Jan-01	95 + 0.10	85 + 0.19	93 + 0.10	90 + 0.08	100 + 0	100 + 0
Feb-01	100 + 0	90 + 0.12	93 + 0.10	78 + 0.26	78 +0.32	100 + 0
Mar-01	100 + 0	93 + 0.05	93 + 0.1	90 + 0.08	95 + 0.06	100 + 0
Apr-01	100 + 0	100 + 0	95 + 0.06	93 + 0.10	95 + 0.06	100 + 0
May-01	88 + 0.13	97 + 0.06	90 + 0.08	90 + 0.12	90 + 0.08	100 + 0
Jun-01	88 + 0.10	98 + 0.05	98 + 0.05	98 + 0.05	98 + 0.05	100 + 0
Jul-01	90 + 0.14	93 + 0.10	98 + 0.05	100 + 0	93 + 0.10	98 + 0.05
Aug-01	95 + 0.10	95 + 0.06	98 + 0.05	95 + 0.06	98 + 0.05	98 + 0.05
Sep-01	98 + 0.05	100 + 0	90 + .08	100 + 0	100 + 0	100 + 0

* Statistically significant event (P=0.05). Statistics were computed between all site means and the DMC ambient water sample.

** Not a statistically significant event due to high variability in the response.
*** DMC water failed to meet the survival (≥ 80%) acceptability criteria.

Table 4
***Pimephales promelas* (Fathead Minnow) Mean Growth**
(In Milligrams + Standard Deviation)

DATE	SITE LOCATION B	C	D	F	Ambient (DMC)	Laboratory Control
Oct-00	0.66 + 0.04	0.46 + 0.15 *	0.58 + 0.09 *	0.67 + 0.02	0.68 + 0.03	0.58 + 0.11
Nov-00	0.29 + 0.05	0.05 + 0.03 *	0.07 + 0.05 *	0.21 + 0.04 *	0.28 + 0.02	0.31 + 0.05
Dec-00	0.72 + 0.06	0.40 + 0.13 *	0.49 + 0.14 *	0.67 + 0.12	0.74 + 0.16**	0.60 + 0.17
Jan-01	0.63 + 0.09	0.50 + 0.08	0.59 + 0.08	0.55 + 0.03	0.58 + 0.05	0.57 + 0.04
Feb-01	0.54 +0.07 *	0.53 + 0.02 *	0.64 + 0.03	0.61 + 0.03	0.68 + 0.9	0.65 + 0.05
Mar-01	0.61 + 0.04	0.66 + 0.03	0.67 + 0.09	0.63 + 0.04	0.64 + 0.11	0.60 + 0.05
Apr-01	0.64 + 0.13	0.72 + 0.06	0.71 + 0.06	0.73 + 0.04	0.67 + 0.05	0.57 + 0.08
May-01	0.45 + 0.02	0.45 + 0.03	0.46 + 0.03	0.43 + 0.06	0.45 + 0.05	0.46 + 0.02
Jun-01	0.61 + 0.1 *	0.83 + 0.07	0.85 + 0.06	0.85 + 0.07	0.74 + 0.05	0.65 + 0.05
Jul-01	0.42 + 0.06	0.39 + 0.04	0.48 + 0.07	0.47 + 0.05	0.45 + 0.07	0.44 + 0.08
Aug-01	0.43 + 0.05	0.44 + 0.03	0.35 + 0.01	0.38 + 0.01	0.36 + 0.03	0.36 + 0.04
Sep-01	0.43 + 0.03	0.43 + 0.08	0.44 + 0.12	0.42 + 0.02	0.34 + 0.04	0.56 + 0.06

* Statistically significant event (P=0.05). Statistics were computed between all site means and the DMC ambient water sample.

** Not a statistically significant event due to high variability in the response.

duction for WY 2001: May (Site B), June (Sites B, C, and D) and August (Sites B and D).

All of the concurrent *D. magna* reference toxicant reproduction endpoints were within the control chart limitations.

The DMC ambient control data met the 10 neonates per surviving female minimum reproduction acceptability criterion in all 12 months. The laboratory control met the reproduction acceptability criterion in all but 1 of the months (December, 2000).

Previous significant tests included 2 in WY 1997, 4 in WY 1998, 2 in WY 1999, and none in WY 2000.

Chronic 7-Day Fathead Minnow (*Pimephales promelas*) Larval Survival

The fathead minnow toxicity test survival results are presented in Table 3 and in Figures 5, 10, 15, and 20. Three months showed statistically significantly ($p<0.05$) reduced fathead minnow larval survival results when compared to the DMC ambient control water. The reduced survival was observed during the October (Site C), November (Sites C, D, and F), and December (Site C) tests.

The survival data for the fathead minnow larvae indicate an adverse effect for Sites C, D and F from October to December. Site C had the greatest number of occurrences (3 events).

Each concurrent *P. promelas* reference toxicant survival endpoint was within the control chart limits.

Data for the DMC ambient control and the laboratory control met the minimum 80% acceptability criteria for 11 of the 12 months. The DMC failed the 80% acceptability criteria for February 2001, but the laboratory control met this criteria.

When the fathead minnow larval survival results for the 5 years are compared (Tables 12, 13, 14 and 15) it is evident that most statistically significant events occurred during the months of October through March.

During the 5-year period, 60 months, Site B showed no statistical effect on survival of fish. Site C had 16 sampling events of 60 indicating statistical reduction in fish survival, of which 14 were during the wet weather months. Site D had 12 sampling events of 60 indicating statistical reduction in survival of which 11 were during the wet weather months. Site F had 11 sampling events showing statistical reduction in fish survival, of which 8 occurred during the wet weather months.

Chronic 7-Day Fathead Minnow (Pimephales promelas) Larval Growth

The fathead minnow toxicity test growth results are presented in Table 4 and in Figures 2, 7, 12, and 17. During the 12 months of the final year, statistically significant ($p<0.05$) reduced growth rates were observed 10 times during October (Sites C and D), November (Sites C, D, and F), December (Sites C and D), February (Sites B and C) and June (Site B).

Each concurrent *P. promelas* reference toxicant growth endpoint was within the control chart limits. All

Table 5
***Selenastrum capricornutum* Cell Counts (cells/mL) with Variance (%)**
Cell count values expressed as the exponent 10^5.
(Selenate added)

DATE	SITE LOCATION											
	B	Var. (%)	C	Var. (%)	D	Var. (%)	F	Var. (%)	Ambient (DMC)	Var. (%)	Lab Control	Var. (%)
Oct-00	15.0	12.5	15.7	5.9	14.3	3.2	16.1	7.0	14.4	5.8	16.2	4.8
Nov-00	8.3	7.8	7.5	13.0	8.1	5.7	7.6	3.1	7.65 **	18.1	7.9 **	5.6
Dec-00	7.8 *	19.4	13.6	11.0	15.4	11.9	14.9	11.3	13.1	7.1	13.3	9.4
Jan-01	17.3	20.7	21.1	13.9	22.1	4.2	17.8	63.8	0.73 **	67.3	21.5	10.8
Feb-01	11.3 *	10.3	23.8	16.4	21.5	5.1	16.7 *	22.3	22.5	7.9	17.6	5.8
Mar-01	18.9	6.3	24.6	17.5	20.0	26.7	21.7	33.3	18.4	15.2	23.5	12.4
Apr-01	9.9	18.0	10.5	10.3	10.2	16.5	5.8 *	16.1	10.7	16.3	20.2	8.3
May-01	10.1 *	4.2	18.4	5.4	13.1	15.8	19.6	16.3	15.5	4.0	14.4	6.8
Jun-01	4.2 *	14.9	12.9 *	11.3	10.3 *	14.9	14.7 *	16.8	21.8	7.0	16.4	15.3
Jul-01	8.3	8.7	8.5	4.7	8.5	14.8	9.4	21.8	8.0 **	12.3	9.1 **	14.0
Aug-01	10.4 *	13.2	12.4	4.8	3.0 *	11.3	15.6	7.8	13.8	10.9	10.0	14.0
Sep-01	6.5 *	13.7	13.0	13.7	11.3	10.7	12.3	25.6	10.8	11.4	9.6	10.3

* Statistically significant event (P=0.05). Statistics were computed between all site means and the DMC ambient water sample.

** DMC/Control water failed to meet the growth ($\geq 1 \times 10^6$) acceptability criteria.

Figure 6
Site C Compared to Delta Mendota Canal—Chronic Endpoints

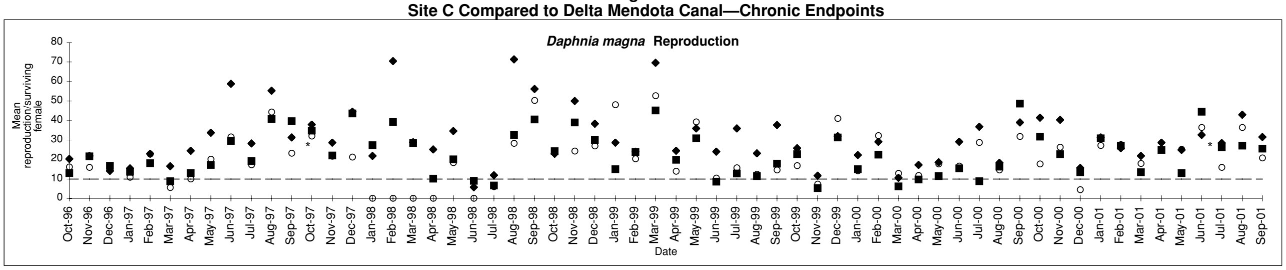


Figure 7
Site C Compared to Delta Mendota Canal—Chronic Endpoints

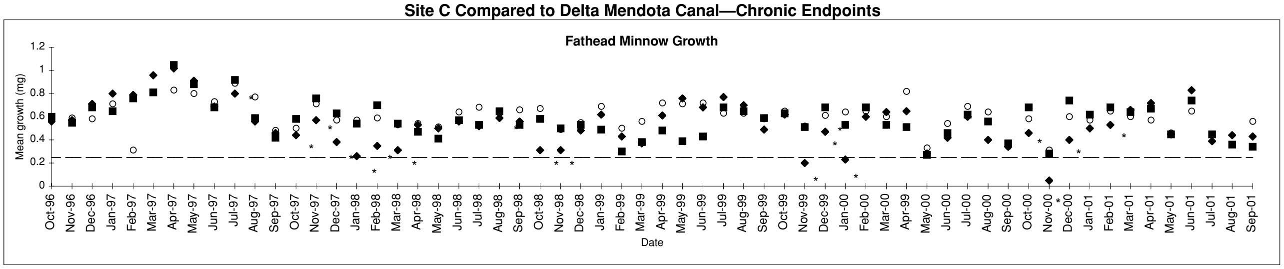


Figure 8
Site C Compared to Delta Mendota Canal—Chronic Endpoints

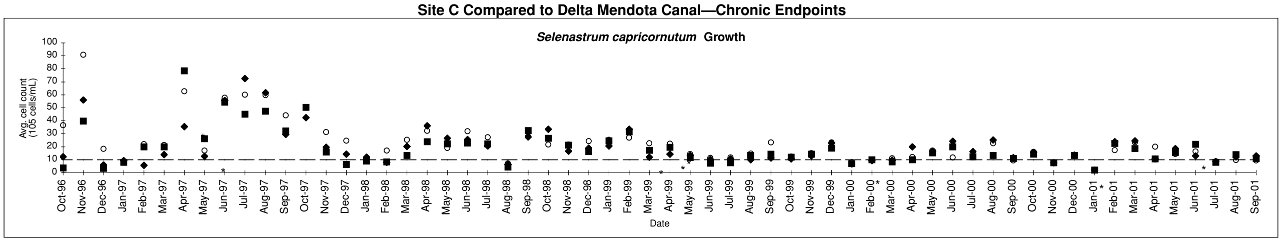


Figure 9
Site C Compared to Delta Mendota Canal—Acute Endpoints

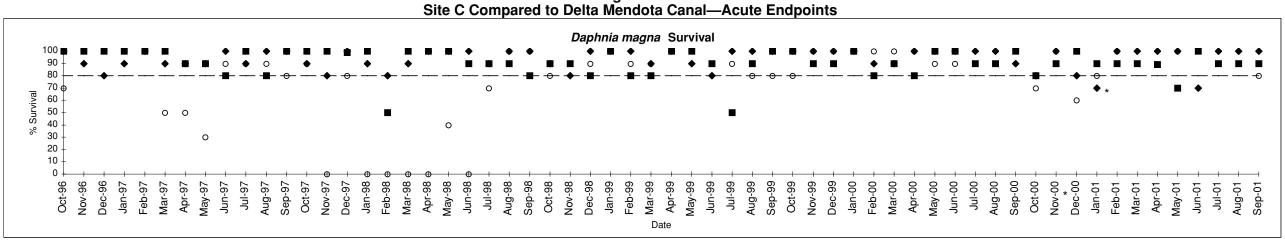
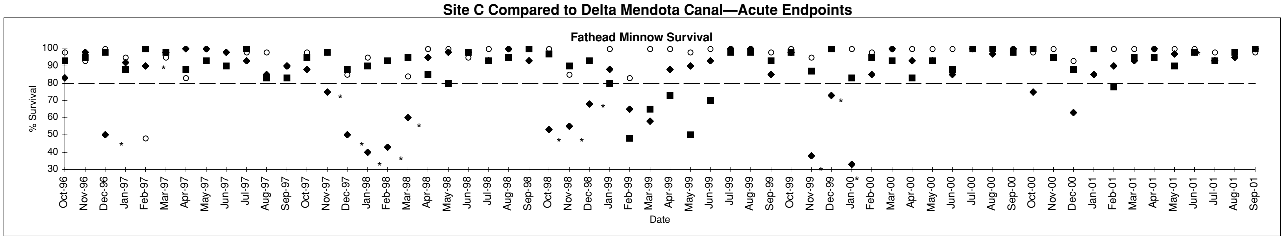


Figure 10
Site C Compared to Delta Mendota Canal—Acute Endpoints



■ Delta Mendota Canal (control)
◆ Site C
* Results statistically different from control
○ Laboratory Control
-- Minimum test acceptability for control

Figure 11
Site D Compared to Delta Mendota Canal—Chronic Endpoints

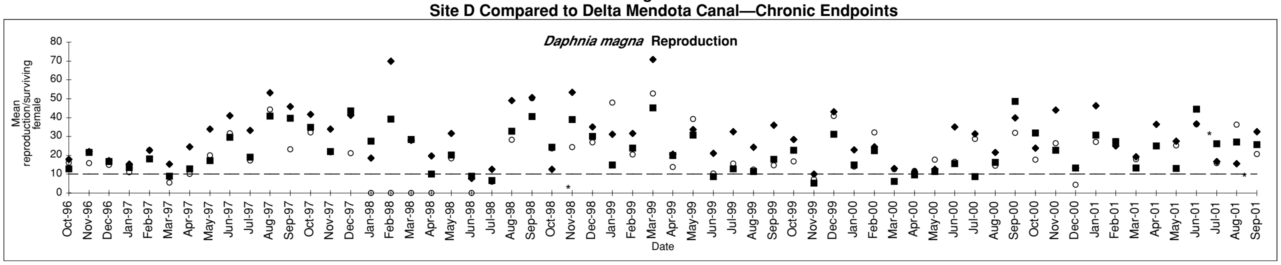


Figure 12
Site D Compared to Delta Mendota Canal—Chronic Endpoints

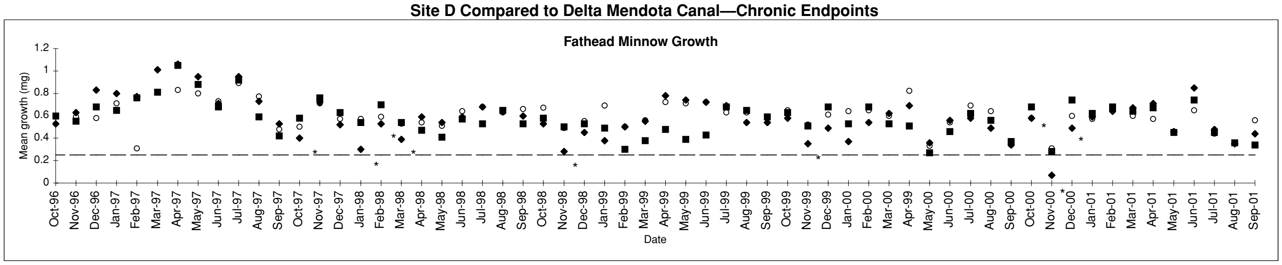


Figure 13
Site D Compared to Delta Mendota Canal—Chronic Endpoints

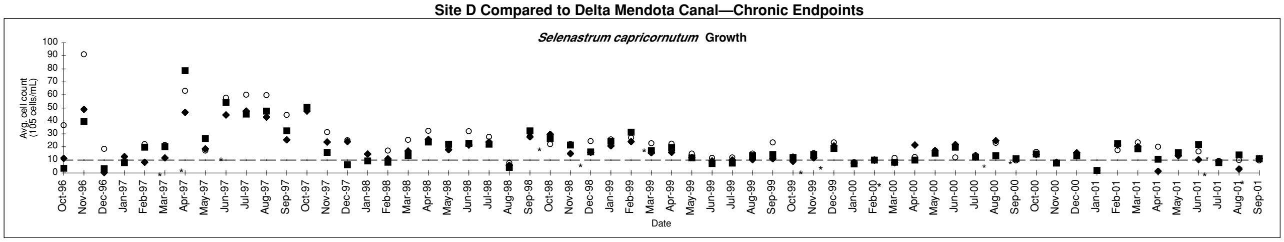


Figure 14
Site D Compared to Delta Mendota Canal—Acute Endpoints

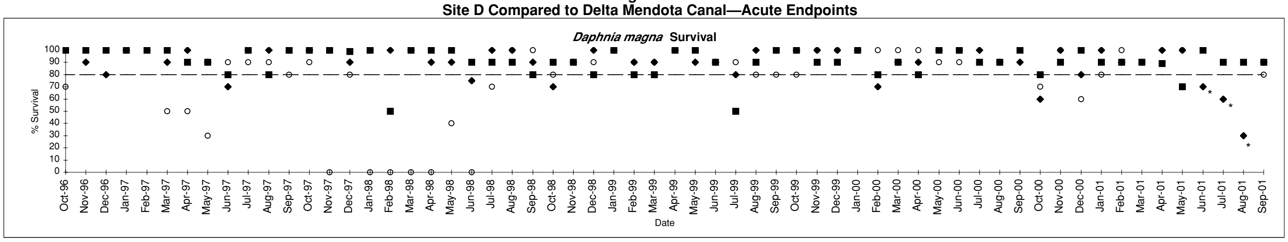
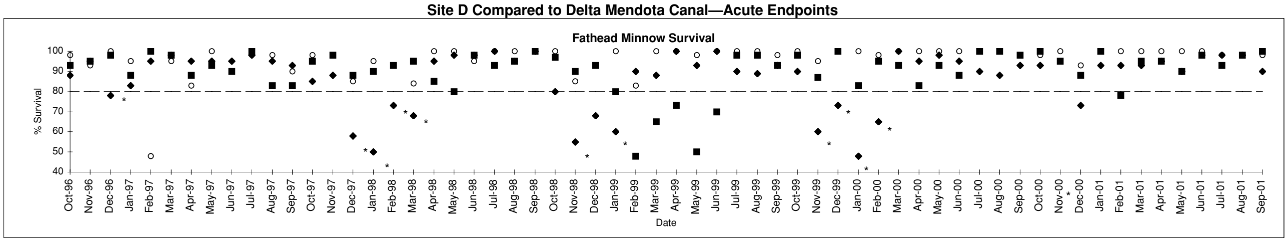


Figure 15
Site D Compared to Delta Mendota Canal—Acute Endpoints



■ Delta Mendota Canal (control)
◆ Site D
* Results statistically different from control
❍ Laboratory Control
-- Minimum test acceptability for control

data for the DMC ambient control and the laboratory control met the 0. 25 mg/surviving adult minimum growth acceptability criterion as shown in Table 4.

Over the 5 years, Site C had most statistically significant events, 17, for reduced fish growth. Most of these events, 12, were during the November-March wet weather season. Thirteen of these 17 events also coincided with reduced fish survival. Site F had 12 sampling events where reduced fish growth was statistically reduced; 9 of the 12 events occurred during the wet weather months. Fish survival was reduced during 10 of these events. Site B had 5 sampling events with signifi-

Table 6 Conductivity (uS) of Site Waters Measured in the Field, Day 1					
	SITE LOCATION				
MONTH	**B**	**C**	**D**	**F**	**Ambient**
Oct-00	3120	1000	700	1150	400
Nov-00	3400	950	1330	1200	435
Dec-00	4350	1500	2120	1460	570
Jan-01	3970	1770	2400	1440	660
Feb-01	3016	1263	1775	964	422
Mar-01	6040	3180	3540	1580	590
Apr-01	3955	1774	3213	1095	655
May-01	4760	1273	3100	1217	416
Jun-01	5000	2010	4110	1410	6380
Jul-01	3975	2483	3714	1124	348
Aug-01	3569	2618	3884	1199	555
Sep-01	4030	930	2226	1274	657

Table 7 Dissolved Oxygen (in mg/L) of Site Waters Measured in the Field, Day 1					
	SITE LOCATION				
MONTH	**B**	**C**	**D**	**F**	**Ambient**
Oct-00	13.8	6.8	6.2	12.9	9.5
Nov-00	13.5	8.8	8.9	11.2	10.3
Dec-00	10.8	8.6	9.1	9.4	10.5
Jan-01	10.5	10.5	10.6	10.4	11.3
Feb-01	12.2	12.3	10.2	11.7	12.4
Mar-01	12.6	8.8	9.8	10.1	9.8
Apr-01	14.7	13.1	12.4	9.2	10.5
May-01	9.2	8.3	8.4	6.3	10.0
Jun-01	11.7	11.2	9.0	7.8	8.7
Jul-01	11.1	9.4	9.5	5.8	8.2
Aug-01	11.5	10.1	9.4	7.3	9.1
Sep-01	10.3	8.3	8.0	7.7	8.3

Table 8 pH of Site Waters Measured in the Field, Day 1					
	SITE LOCATION				
MONTH	**B**	**C**	**D**	**F**	**Ambient**
Oct-00	NT	NT	NT	NT	NT
Nov-00	8.3	7.3	7.5	7.8	7.6
Dec-00	7.7	7.4	7.2	7.8	7.5
Jan-01	7.6	7.2	7.1	8.1	7.6
Feb-01	7.4	7.2	7.3	7.6	7.3
Mar-01	8.0	7.9	7.8	7.4	7.6
Apr-01	NA	NA	NA	NA	NA
May-01	8.4	8.1	8.2	7.6	8.2
Jun-01	8.2	8.8	8.6	7.6	8.8
Jul-01	8.3	8.0	8.3	7.6	8.0
Aug-01	8.4	8.1	8.4	7.7	8.0
Sep-01	8.5	7.7	8.1	7.7	7.9

NA - Not Available
NT - Not Taken

Figure 16
Site F Compared to Delta Mendota Canal—Chronic Endpoints

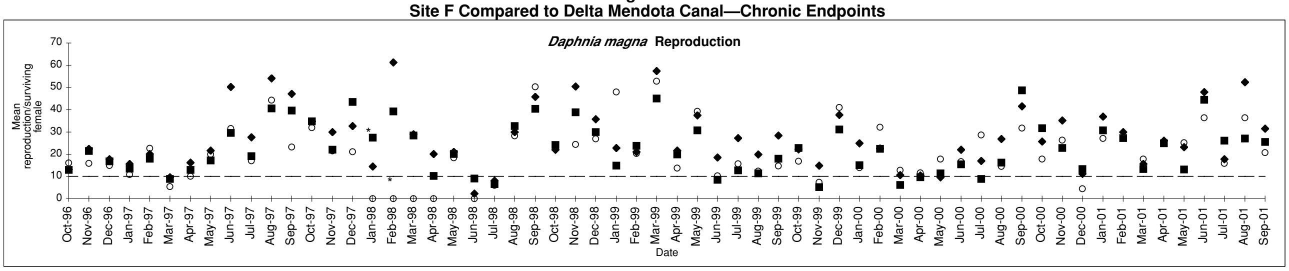


Figure 17
Site F Compared to Delta Mendota Canal—Chronic Endpoints

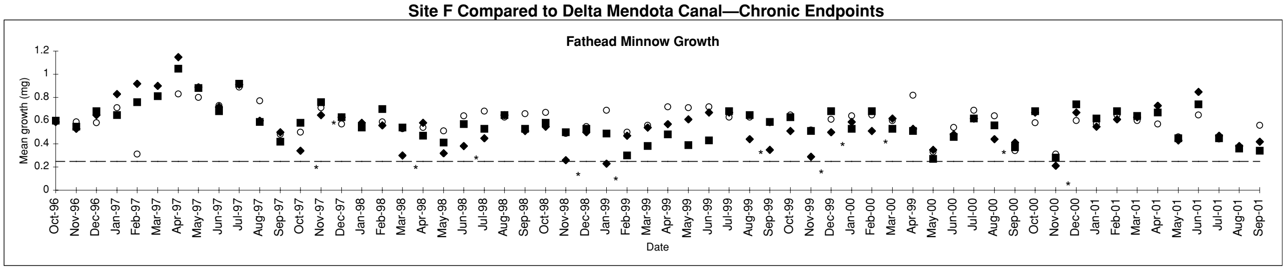


Figure 18
Site F Compared to Delta Mendota Canal—Chronic Endpoints

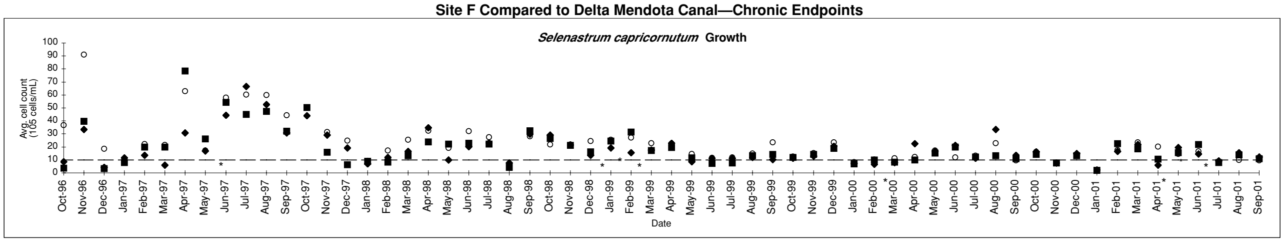


Figure 19
Site F Compared to Delta Mendota Canal—Acute Endpoints

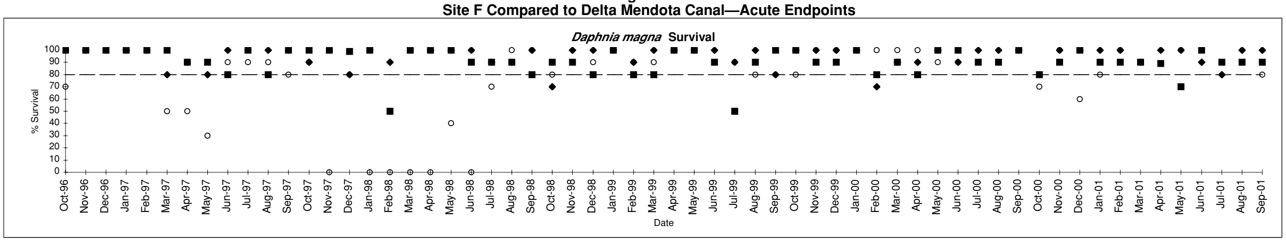
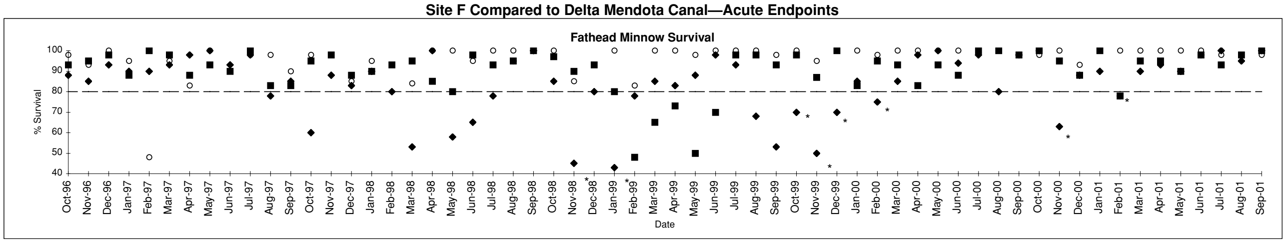


Figure 20
Site F Compared to Delta Mendota Canal—Acute Endpoints



■ Delta Mendota Canal (control)
◆ Site F
* Results statistically different from control
❍ Laboratory Control
-- Minimum test acceptability for control

cantly reduced growth (3 during the wet season). Site D had 10 sampling events in which fish growth was reduced. Seven of these sampling events were during the wet season and 6 sampling events had reduced fish survival.

Selenastrum capricornutum 96-Hour Growth Test

The algal growth results are presented in Table 5 and in Figures 3, 8, 13, and 18. Twelve tests during 6 months produced statistically significant ($p<0.05$)

Table 9 Temperature (deg. Celsius) of Site Waters Measured in the Field, Day 1					
	SITE LOCATION				
MONTH	B	C	D	F	Ambient
Oct-00	22.5	22.0	21.5	21.0	22.0
Nov-00	11.4	10.2	10.1	10.6	12.8
Dec-00	12.5	12.6	12.4	12.5	10.9
Jan-01	9.4	10.2	9.8	9.0	9.8
Feb-01	9.1	9.6	8.8	9.0	9.7
Mar-01	14.8	15.8	14.6	15.0	13.8
Apr-01	13.2	13.5	13.4	12.3	14.3
May-01	22.2	22.5	22.2	19.9	16.8
Jun-01	24.0	24.0	24.0	22.5	21.5
Jul-01	27.0	26.2	26.5	25.4	25.3
Aug-01	24.4	24.8	24.7	23.1	25.1
Sep-01	21.0	22.5	22.3	20.8	23.4

Table 10 Depth of Sample Point (in feet), Day 1					
	SITE LOCATION				
MONTH	B	C	D	F	Ambient
Oct-00	6.5	5.8	5.1	5.5	16.0
Nov-00	NT	NT	NT	NT	NT
Dec-00	NT	NT	NT	7.9	NT
Jan-01	6.6	5.5	5.5	7.5	17.5
Feb-01	7.0	6.5	6.5	6.8	15.0
Mar-01	7.1	7.8	7.8	5.5	15.0
Apr-01	6.8	5.0	5.0	6.8	15.0
May-01	6.7	5.0	5.0	6.5	15.5
Jun-01	7.0	4.8	4.8	7.5	16.0
Jul-01	7.0	4.5	4.5	7.0	17.0
Aug-01	6.9	4.5	4.5	7.5	16.0
Sep-01	7.5	4.8	4.8	7.2	13.0

NA - Not Available
NT - Not taken

reduced algal growth. The reduced growth was observed during December (Site B), February (Site B and F), April (Site F), May (Site B), June (Sites B, C, D and F), August (Sites B and D) and September (Site B). Site B had 6 statistically significant events. Site B also had the highest number of statistically significant events for the previous 4 water years. During June 2001 all sites had reduced algal growth.

Each concurrent *S. capricornutum* reference toxicant test had growth endpoints within the control chart limitations. However, the variability exceeded the suggested 20% acceptability criterion in 1 out of the 12 tests in March for the DMC control water. Three of the 12 DMC ambient control samples failed to meet the growth ($\geq$ 1x 10^6) acceptability criteria in November, January and July sampling events.

The laboratory control met the minimum algal cell density on all events except three (December, July and September). These results are summarized in Table 5.

This is the 5th year that *S. capricornutum* tests have shown reduced growth in Sites B, D and F.

Definitive Bioassay Testing

Definitive bioassay testing was conducted on site B water samples for all 12 months of WY 2001 (Table 11). The definitive bioassay used a dilution series of the site water at 12. 5, 25, 50, 75, and 100 percent of the site water diluted with water from the DMC (ambient water). The results were compared to the DMC water. Laboratory control water was used as a second control to assure there was no toxicity in the DMC water.

The definitive bioassay method allowed for the determination of the No Observed Effect Concentration

Table 11
Statistical Analysis of Growth Endpoints for Algae at Station B

Test Month	IC 50	IC 25	NOEC	LOEC	Toxic Units
Feb-98	79.16	46.85	>100	>100	<1
Mar-98	83.62	58.83	50	100	2
Apr-98	>100	31.67	25	50	4
Oct-99	NA	NA	NA	NA	NA
Nov-99	>100	87.45	50	100	2
Dec-99	>100	54.44	<6.25	6.25	>16
Jan-00	72.98	38.58	25	50	4
Feb-00	>100	36.68	25	50	4
Mar-00	>100	100	>100	>100	<1
Apr-00	>100	>100	>100	>100	<1
May-00	>100	>100	>100	>100	<1
Jun-00	>100	>100	12.5	25	8
Jul-00	>100	>100	>100	>100	<1
Aug-00	>100	>100	>100	>100	<1
Sep-00	NA	NA	<6.25	6.25	>16
Oct-00	>100	>100	>100	>100	<1
Nov-00	>100	>100	>100	>100	<1
Dec-00	>100	40.91	25	50	4
Jan-01	3.67	1.84	<6.25	6.25	>16
Feb-01	>100	55.36	12.5	25	8
Mar-01	>100	>100	>100	>100	<1
Apr-01	>100	>100	>100	>100	<1
May-01	>100	81.72	50	100	2
Jun-01	75.53	12.82	<12.5	12.5	>8
Jul-01	>100	>100	50	75	2
Aug-01	>100	63.49	<12.5	12.5	>8
Sep-01	>100	23.29	>100	>100	<1

IC - Inhibition concentration: The toxicant concentration that would cause a given percent (i.e. 50% or 25%) reduction in a biological measurement (in this case, algal growth).

NOEC - No observed effect concentration: The highest concentration of toxicant to which organisms are exposed that causes no observable adverse effects.

LOEC - Lowest observed effect concentration: The lowest concentration of toxicant to which organisms are exposed which causes adverse effects.

Toxic Units: 100/NOEC. Toxicity units are used to standardize the results of toxicity tests regardless of the statistical endpoint used.

(NOEC). The NOEC is a statistically derived calculation of the amount of the test water dilution needed to eliminate those adverse effects that are measured by these tests. For example, in December 2000, the NOEC was 25 (Table 11). Therefore, a dilution of 25% of test water with 75% of ambient water was needed for the endpoint to not differ statistically from the control.

Results from the 12 monthly definitive tests for WY 2001 (Table 11) showed five samples that did not exhibit toxicity at full-strength test water (October, November, March, April, and September), two samples with a NOEC of 50 percent (May and July), one sample with a NOEC of 25 percent (December), one sample with a NOEC of 12. 5 percent (February), two samples with a NOEC less than 12. 5 (June and August) and one sample with a NOEC of less than 6. 5 percent (January).

These data also can be expressed in toxicity units (TU = 100/NOEC) (Table 11). In general, toxicity units are used to standardize the results of toxicity tests regardless of the statistical endpoint used. In the example given above for December 2000, the NOEC was 25, equivalent to 4 TU. A compilation of data for 26 months in which definitive bioassay testing of algae took place during the five years of the GBP (Table 11) showed

Table 12. Summary of Statistically Significant Results — Station B

Fathead Minnow Survival

WY	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June	July	Aug	Sept
1997												
1998												
1999												
2000												
2001												

Fathead Minnow Growth

WY	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June	July	Aug	Sept
1997					*							
1998	*	*										
1999												
2000												
2001					*				*			

Daphnia magna Survival

WY	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June	July	Aug	Sept
1997												
1998												
1999												
2000												
2001								*	*		*	

Daphnia magna Reproduction

WY	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June	July	Aug	Sept
1997												*
1998				*								
1999	*											
2000												
2001								*	*		*	

Algae Growth

WY	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June	July	Aug	Sept
1997			*		*	*	*		*			*
1998	*			*	*	*		*	*			*
1999	*	*	*	*	*						*	
2000		*	*	*	*							
2001			*		*			*	*		*	*

three months with greater than 16 TU (December 1999; September 2000; and January 2001). During this time, the drain water must be diluted more than sixteen to one to eliminate those toxic effects of the drain water that are measured by these tests. In addition, four episodes of toxicity occurred with TUs equal to or greater than 8 (June 2000; February, June, and August 2001) and four episodes of toxicity occurred with TUs of 4 (April 1998; January, February and December 2000).

Water Chemistry

Selenium

The selenium data are presented in Figure 21 and Table 16. As for the previous water years, Site B had the highest selenium concentrations with the months of March and April having the highest concentrations (>74 mg/L). The July and August 2001 sampling events had the lowest selenium concentrations of 32 to 39mg/L. As for the previous water year, Site D showed the same trends as site B with an approximate difference of 50-70% for the period October through April and then approaching the same concentrations as site B for the period June through August.

Sulfate

The sulfate results are presented in Figure 22 and Table 17. Sulfate concentrations followed similar trends as selenium concentrations for the same sites. Site B had the highest concentrations of sulfate with peaks up to 2000 mg/L in April 2001. High concentrations of sulfate were also observed in May and June. Site D followed the

Table 13. Summary of Statistically Significant Results — Station C

Fathead Minnow Survival

WY	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June	July	Aug	Sept
1997			*		*							
1998		*	*	*	*	*						
1999	*	*	*									
2000		*	*	*								
2001	*	*	*									

Fathead Minnow Growth

WY	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June	July	Aug	Sept
1997										*		
1998	*	*	*	*	*	*					*	
1999	*	*										
2000		*	*	*								
2001	*	*	*		*							

Daphnia magna Survival

WY	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June	July	Aug	Sept
1997												
1998												
1999												
2000												
2001				*					*			

Daphnia magna Reproduction

WY	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June	July	Aug	Sept
1997												*
1998												
1999												
2000												
2001									*			

Algae Growth

WY	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June	July	Aug	Sept
1997					*		*	*				
1998												
1999						*	*					
2000												
2001									*			

same trends as Site B and also showed the same relationship to Site B as the selenium concentrations.

Other Water Chemistry

The laboratory water chemistry data are presented in Figures 23–30 and Tables 18 through 27. All analyses were performed at the BES Laboratory, except for selenium and sulfate. Tables 6–9 provide water chemistry data collected in the field for conductivity, DO, pH, and temperature for the first day the sample set was collected. The conductivity was higher for Site B water for all months except July 2001. Site C and F had the lowest conductivity. The DO and pH of all stations were similar, with Site F showing the lowest pH on average. The Site B water is about three times greater in hardness than the other stations, exceeding 1000 mg/L (as $CaCO_3$) during January 2001 and March through June 2001. Total suspended solids were generally higher in Site C and F water and lowest in Site B water. Suspended solids remain higher from February through September at sites C, D and F. No trend in alkalinity was observed except that Site F is lower than the other stations sampled. The highest ammonia nitrogen concentration was observed in April 2001 at Site F (19. 52 mg/L). The total chlorine concentration ranged from non-detectable to 1. 0 mg/L for all sites sampled.

Conclusions

A total of 240 laboratory toxicity endpoints (4 sites, 12 months, and 5 tests from 3 species) compared waters from sites B, C, D, and F to the ambient control

Table 14. Summary of Statistically Significant Results — Station D

Fathead Minnow Survival

WY	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June	July	Aug	Sept
1997			*									
1998			*	*	*	*						
1999		*		*								
2000		*	*	*	*							
2001		*										

Fathead Minnow Growth

WY	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June	July	Aug	Sept
1997	*											
1998	*			*	*	*						
1999		*										
2000		*										
2001	*	*	*									

Daphnia magna Survival

WY	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June	July	Aug	Sept
1997												
1998												
1999												
2000												
2001	*								*	*	*	

Daphnia magna Reproduction

WY	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June	July	Aug	Sept
1997												
1998				*								
1999	*											
2000												
2001									*		*	

Algae Growth

WY	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June	July	Aug	Sept
1997			*		*	*		*				
1998												*
1999		*			*							
2000	*	*										
2001									*		*	

(DMC) between October 2000 and September 2001. Each set of tests included 5 toxicity endpoints (minnow survival, minnow growth, water flea survival, water flea reproduction, and algae growth). Of these tests, 42 of the 240 possible (17. 5 %) exhibited statistically significant reduced endpoints ($P<0.05$) compared to the ambient control tests (Site B = 14, Site C = 11, Site D = 12, and Site F = 5). Previous years had 25, 28, 44 and 24 for 2000, 1999, 1998 and 1997 water years, respectively.

The *Daphnia magna* was the least sensitive of the species tested, accounting for 5 significant responses for reproduction and 8 for survival during the WY 2001. For WY 1997 and 2000 there were no tests that showed significant reductions in survival of *D. magna*. During WY 1998, 1999 and 2000, there were 4, 2, and 0 responses, respectively to *D. magna* reproduction.

The algae exposed to Site B water exhibited reduced growth when compared to DMC ambient control water in 5 out of 12 months. Comparisons to previous years were 4 in WY 2000, 6 in WY 1999, 7 in WY 1998, 6 in WY 1997.

The larval fathead minnow test showed 15 significant responses, using survival and growth as the endpoint. The majority of these responses were during the winter months (October 2000 through February 2001) at Sites C, D, and F. Statistically significant events are summarized in Tables 12 through 15.

Table 15. Summary of Statistically Significant Results — Station F

Fathead Minnow Survival

WY	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June	July	Aug	Sept
1997												
1998	*				*	*			*			
1999		*		*								
2000	*	*	*		*							
2001		*										

Fathead Minnow Growth

WY	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June	July	Aug	Sept
1997												
1998	*	*			*	*			*			
1999		*		*							*	
2000		*	*		*							
2001		*										

Daphnia magna Survival

WY	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June	July	Aug	Sept
1997												
1998												
1999												
2000												
2001												

Daphnia magna Reproduction

WY	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June	July	Aug	Sept
1997												
1998				*	*							
1999												
2000												
2001												

Algae Growth

WY	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June	July	Aug	Sept
1997						*	*	*				
1998								*				
1999			*	*	*							
2000					*							
2001					*		*		*			

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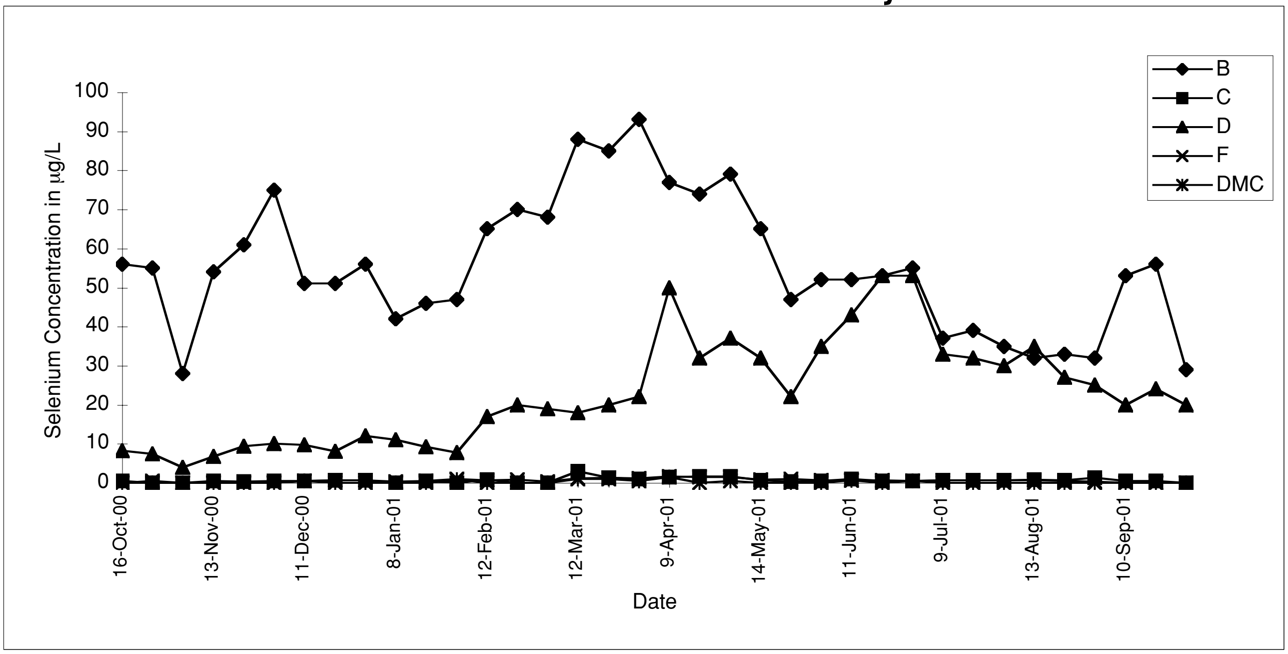
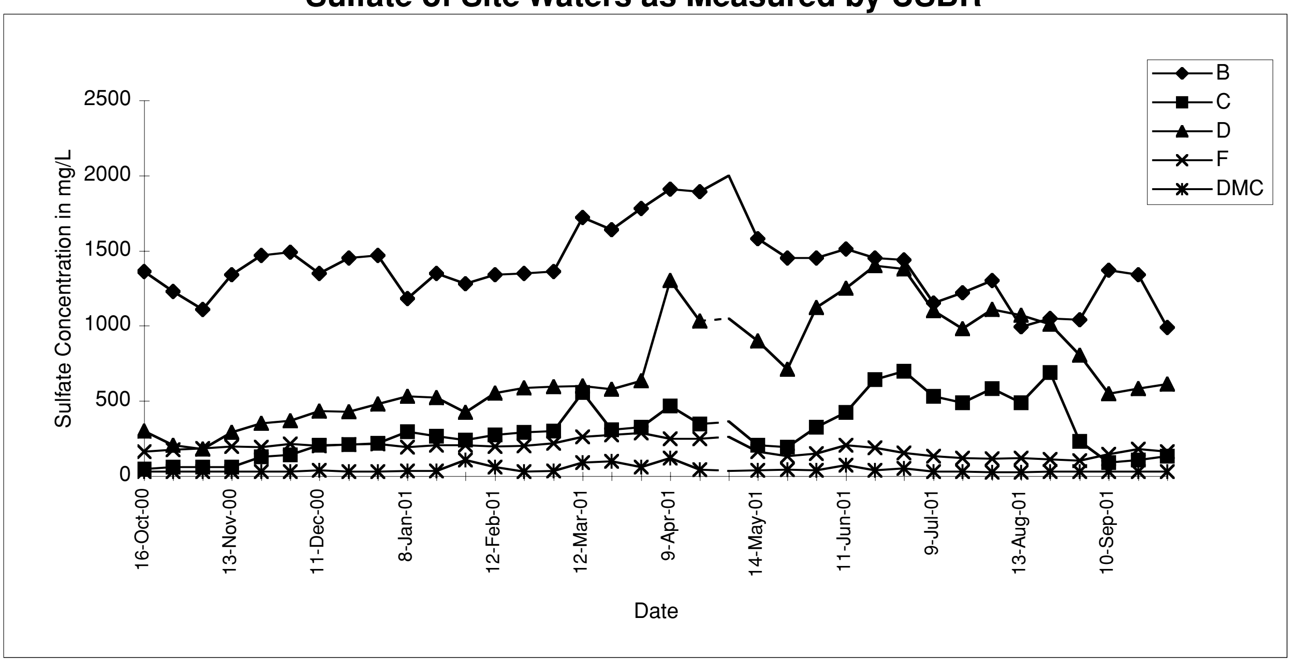
Figure 21
Selenium of Site Waters as Measured by USBR



Detection limit 0.40 µg/L for all tests

Figure 22
Sulfate of Site Waters as Measured by USBR



Data for April 7 not available

Figure 23
Conductivity of Site Waters as Measured at BES Laboratory

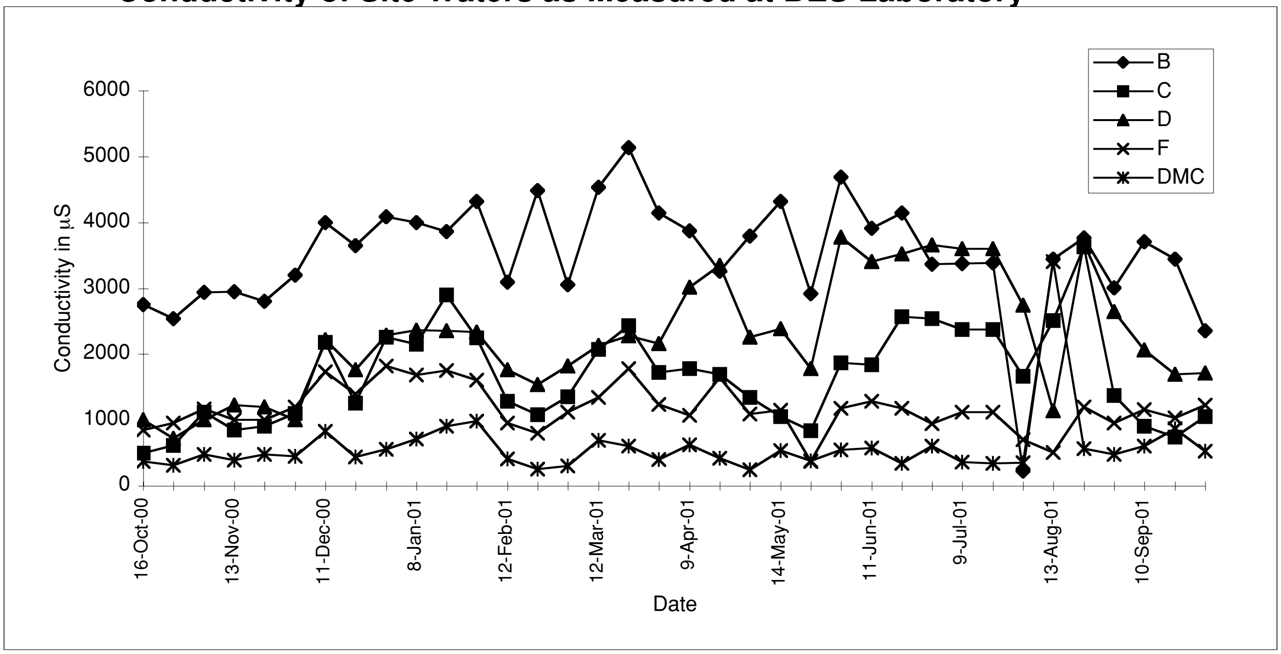


Figure 24
Total Suspended Solids of Site Waters as Measured at BES Laboratory

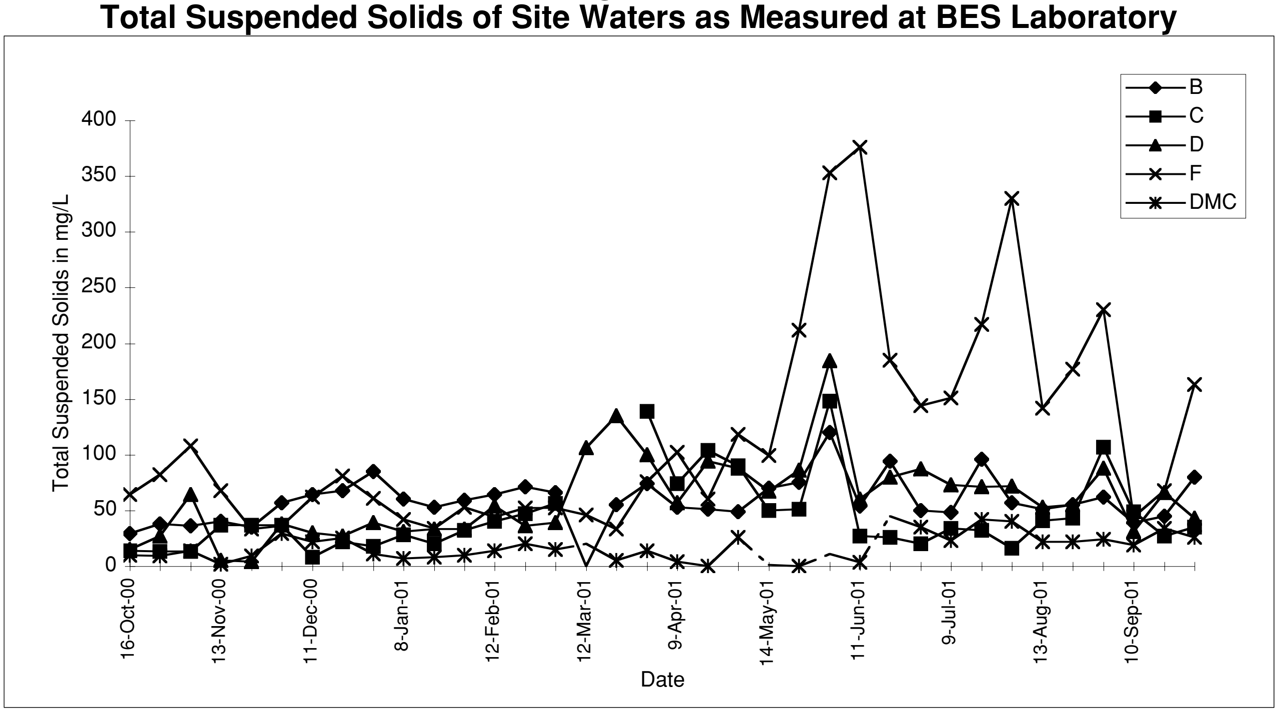


Figure 25
Dissolved Oxygen of Site Waters as Measured at the BES Laboratory

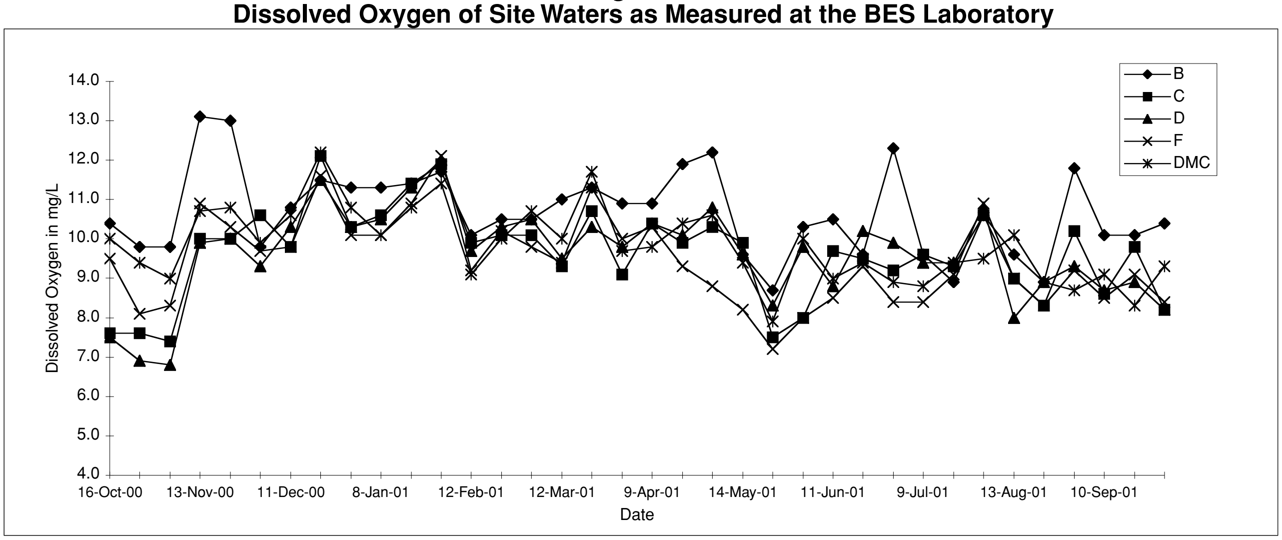


Figure 26
pH of Site Waters as Measured at the BES Laboratory

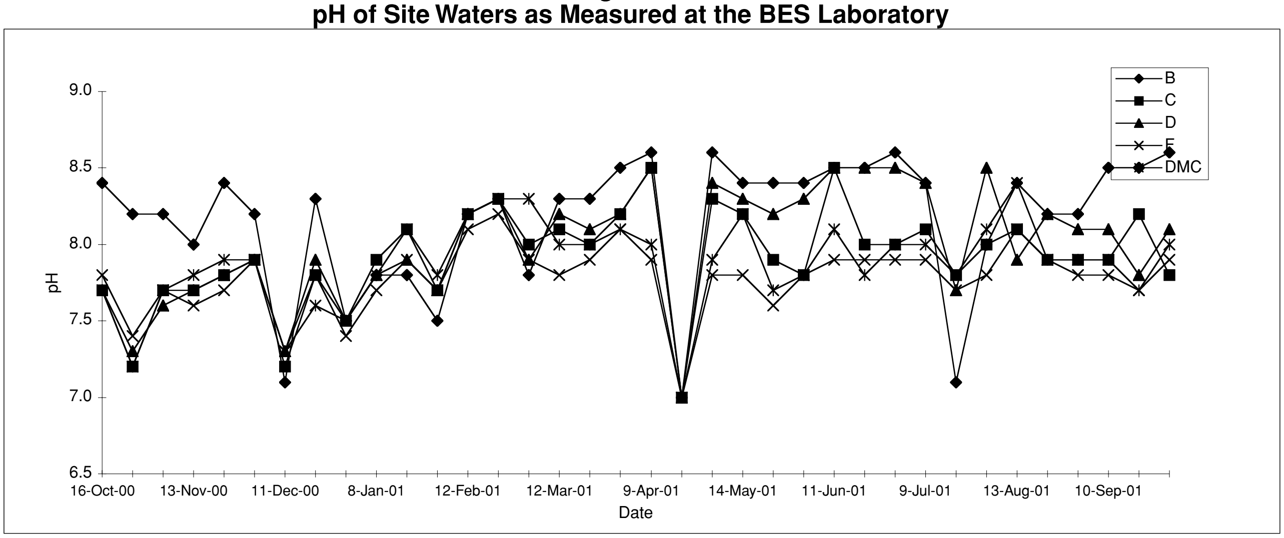
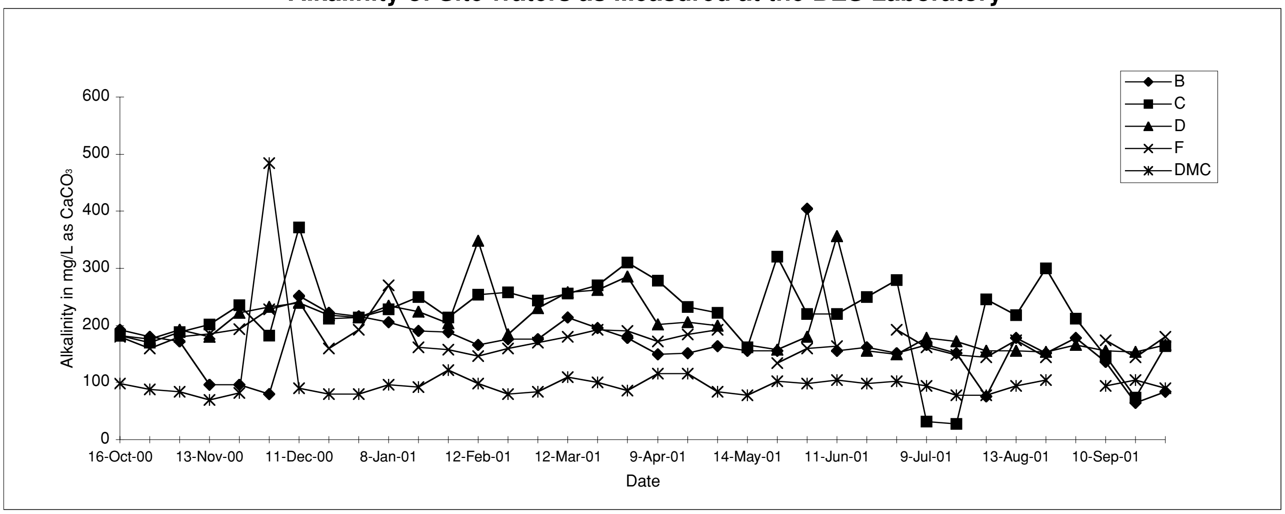


Figure 27
Alkalinity of Site Waters as Measured at the BES Laboratory



* Measurement Not Available (NA) for Site B

Figure 28
Hardness of Site Waters as Measured at the BES Laboratory

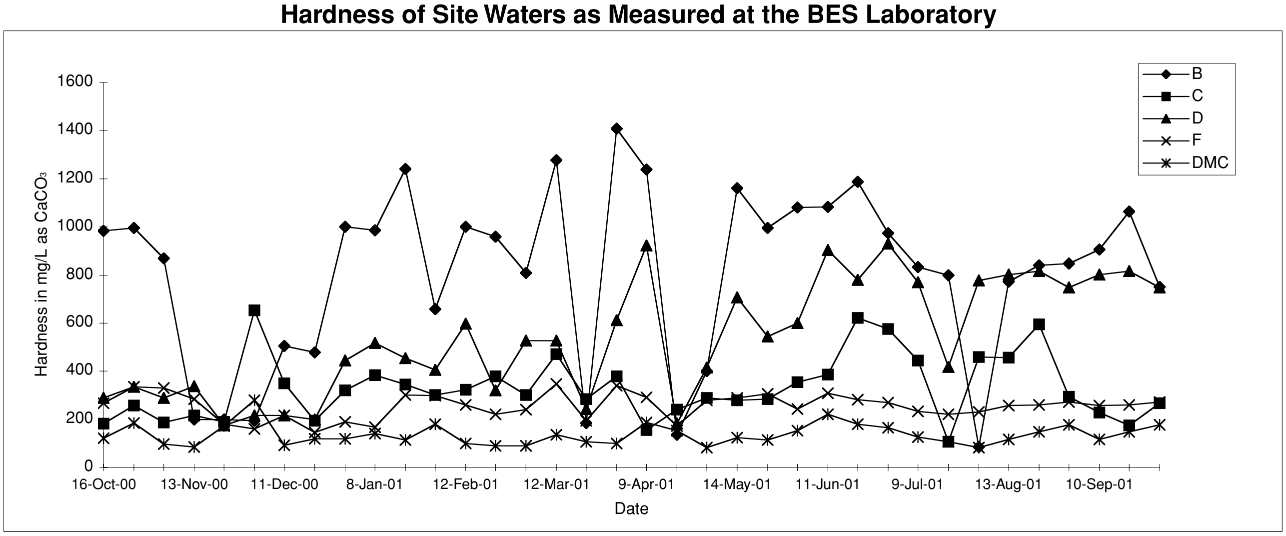


Figure 29
Ammonia of Site Waters as Measured at the BES Laboratory

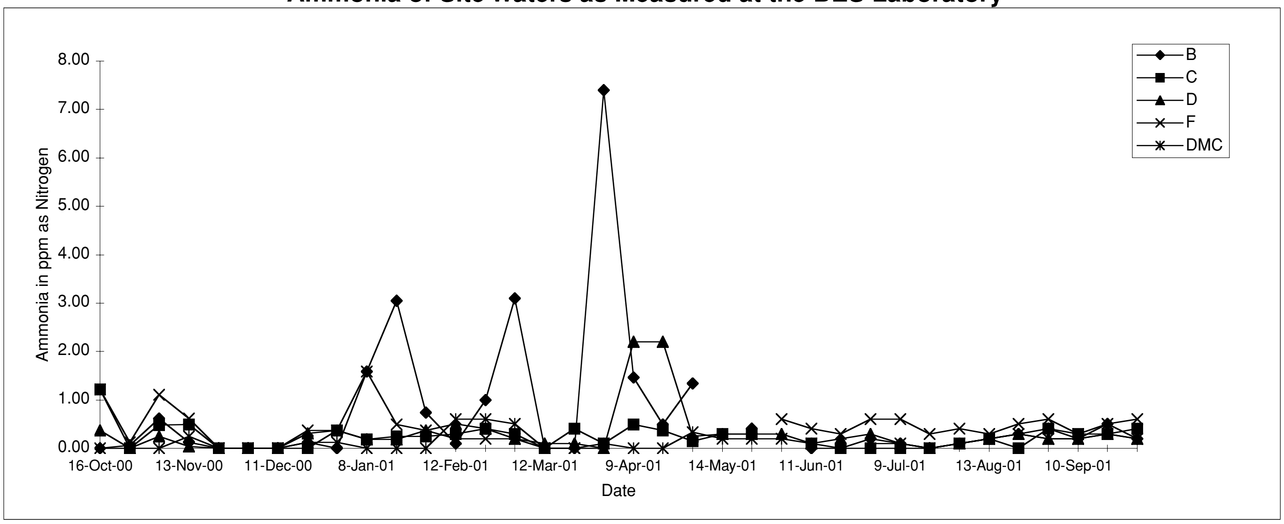
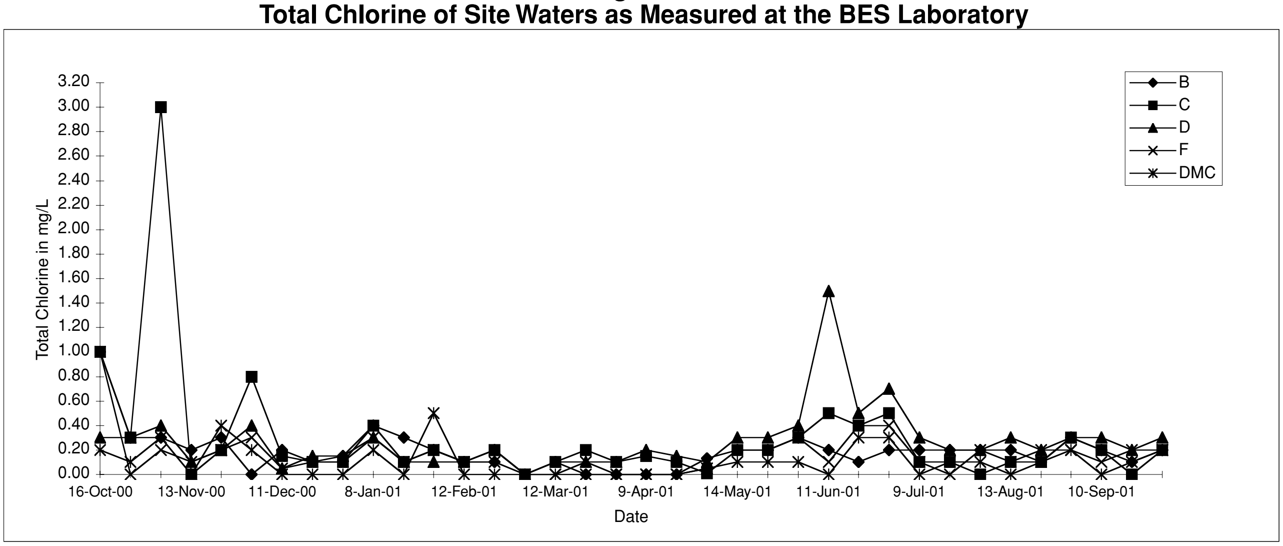


Figure 30
Total Chlorine of Site Waters as Measured at the BES Laboratory



0.0 Corresponds to a non-detectable concentration (i.e. <0.1)

TABLE 16. Selenium (μg/L) as Measured by the Bureau of Reclamation

MONTH	SAMPLE DATE	SITE LOCATION B	C	D	F	DMC
Oct-00	16-Oct-00	56	0.5	8.3	<0.4	<0.4
	18-Oct-00	55	<0.4	7.4	0.5	<0.4
	20-Oct-00	28	<0.4	3.9	<0.4	<0.4
Nov-00	13-Nov-00	54	0.5	6.7	<0.4	<0.4
	15-Nov-00	61	0.4	9.4	<0.4	<0.4
	17-Nov-00	75	0.5	10	<0.4	<0.4
Dec-00	11-Dec-00	51	0.5	9.8	0.5	0.5
	13-Dec-00	51	0.6	8.1	0.7	<0.4
	15-Dec-00	56	0.6	12	0.6	<0.4
Jan-01	8-Jan-01	42	<0.4	11	0.4	<0.4
	10-Jan-01	46	0.5	9.3	0.5	<0.4
	12-Jan-01	47	<0.4	7.7	1	0.8
Feb-01	12-Feb-01	65	0.8	17	0.6	<0.4
	14-Feb-01	70	<0.4	20	0.8	<0.4
	16-Feb-01	68	<0.4	19	0.4	<0.4
Mar-01	12-Mar-01	88	2.9	18	1.2	1
	14-Mar-01	85	1.3	20	1.3	1
	16-Mar-01	93	1	22	1.2	0.5
Apr-01	9-Apr-01	77	1.5	50	1.7	1.5
	11-Apr-01	74	1.7	32	1.5	<0.4
	13-Apr-01	79	1.7	37	1.5	0.5
May-01	14-May-01	65	0.7	32	0.8	<0.4
	16-May-01	47	0.4	22	1	<0.4
	18-May-01	52	0.5	35	0.6	<0.4
Jun-01	11-Jun-01	52	1	43	0.6	0.6
	13-Jun-01	53	0.5	53	0.7	<0.4
	15-Jun-01	55	0.5	53	0.5	0.5
Jul-01	9-Jul-01	37	0.7	33	0.6	<0.4
	11-Jul-01	39	0.7	32	0.6	<0.4
	13-Jul-01	35	0.6	30	0.7	<0.4
Aug-01	13-Aug-01	32	0.9	35	0.6	<0.4
	15-Aug-01	33	0.6	27	0.5	<0.4
	17-Aug-01	32	1.3	25	0.4	<0.4
Sep-01	10-Sep-01	53	0.5	20	<0.4	<0.4
	12-Sep-01	56	0.5	24	<0.4	<0.4
	14-Sep-01	29	<0.4	20	<0.4	<0.4

TABLE 17. Sulfate (mg/L) as Measured by the Bureau of Reclamation

MONTH	SAMPLE DATE	SITE LOCATION				
		B	C	D	F	DMC
Oct-00	16-Oct-00	1360	47	299	162	28
	18-Oct-00	1230	60	205	175	28
	20-Oct-00	1110	61	180	185	28
Nov-00	13-Nov-00	1340	61	293	196	29
	15-Nov-00	1470	130	352	192	30
	17-Nov-00	1490	142	367	213	28
Dec-00	11-Dec-00	1350	207	432	201	39
	13-Dec-00	1450	209	426	209	29
	15-Dec-00	1470	219	481	213	29
Jan-01	8-Jan-01	1180	297	532	193	34
	10-Jan-01	1350	267	521	205	36
	12-Jan-01	1280	239	423	205	105
Feb-01	12-Feb-01	1340	276	553	199	60
	14-Feb-01	1350	290	588	202	31
	16-Feb-01	1360	299	595	220	33
Mar-01	12-Mar-01	1720	555	599	263	90
	14-Mar-01	1640	307	576	274	98
	16-Mar-01	1780	326	635	286	59
Apr-01	9-Apr-01	1910	465	1300	247	122
	11-Apr-01	1890	346	1030	250	44
	13-Apr-01	2000	366	1050	263	34
May-01	14-May-01	1580	204	898	162	40
	16-May-01	1450	191	709	132	41
	18-May-01	1450	324	1120	148	40
Jun-01	11-Jun-01	1510	423	1250	204	74
	13-Jun-01	1450	640	1400	187	37
	15-Jun-01	1440	698	1380	153	53
Jul-01	9-Jul-01	1150	529	1100	134	28
	11-Jul-01	1220	489	980	120	28
	13-Jul-01	1300	583	1110	115	26
Aug-01	13-Aug-01	995	490	1070	122	26
	15-Aug-01	1050	691	1010	113	28
	17-Aug-01	1040	231	804	102	30
Sep-01	10-Sep-01	1370	90	547	144	30
	12-Sep-01	1340	108	581	178	32
	14-Sep-01	988	131	614	164	32

TABLE 18. Conductivity (μS) of Site Waters as Received at the BES Laboratory

MONTH	SAMPLE DATE	SITE LOCATION				
		B	C	D	F	DMC
Oct-00	16-Oct-00	2750	500	1000	850	370
	18-Oct-00	2540	610	720	950	310
	20-Oct-00	2940	1120	1000	1170	480
Nov-00	13-Nov-00	2950	850	1230	1000	390
	15-Nov-00	2800	900	1200	1000	480
	17-Nov-00	3200	1100	1000	1200	450
Dec-00	11-Dec-00	4000	2180	2220	1730	830
	13-Dec-00	3650	1250	1760	1390	440
	15-Dec-00	4080	2260	2290	1820	550
Jan-01	8-Jan-01	4000	2150	2360	1680	710
	10-Jan-01	3860	2900	2350	1750	900
	12-Jan-01	4320	2250	2330	1600	980
Feb-01	12-Feb-01	3097	1287	1756	950	413
	14-Feb-01	4480	1080	1540	800	250
	16-Feb-01	3051	1356	1819	1121	297
Mar-01	12-Mar-01	4535	2073	2127	1340	686
	14-Mar-01	5131	2434	2273	1779	599
	16-Mar-01	4141	1717	2158	1235	401
Apr-01	9-Apr-01	3875	1777	3010	1071	625
	11-Apr-01	3254	1690	3343	1643	415
	13-Apr-01	3791	1344	2257	1090	239
May-01	14-May-01	4316	1046	2379	1147	530
	16-May-01	2916	836	1780	372	379
	18-May-01	4683	1863	3775	1173	545
Jun-01	11-Jun-01	3906	1835	3406	1285	571
	13-Jun-01	4145	2565	3521	1175	338
	15-Jun-01	3363	2540	3654	944	606
Jul-01	9-Jul-01	3375	2372	3595	1117	363
	11-Jul-01	3380	2370	3595	1117	340
	13-Jul-01	226	1667	2744	700	349
Aug-01	13-Aug-01	3446	2506	1133	510	3408
	15-Aug-01	3765	3632	3690	1192	566
	17-Aug-01	3005	1367	2643	957	476
Sep-01	10-Sep-01	3709	905	2057	1155	606
	12-Sep-01	3438	740	1692	1030	868
	14-Sep-01	2357	1053	1713	1224	529

TABLE 19. Total Suspended Solids (mg/L) of Site Waters as Received at the BES Laboratory

MONTH	SAMPLE DATE	SITE LOCATION				
		B	C	D	F	DMC
Oct-00	16-Oct-00	29	14	15	64	10
	18-Oct-00	38	13	27	82	9
	20-Oct-00	36	13	64	108	14
Nov-00	13-Nov-00	40	37	5	68	2
	15-Nov-00	35	37	4	33	9
	17-Nov-00	57	37	38	36	29
Dec-00	11-Dec-00	64	8	30	62	22
	13-Dec-00	68	22	27	81	25
	15-Dec-00	85	18	39	61	11
Jan-01	8-Jan-01	60	28	31	42	7
	10-Jan-01	53	20	33	34	8
	12-Jan-01	59	32	33	53	10
Feb-01	12-Feb-01	64	40	54	44	14
	14-Feb-01	71	47	36	52	20
	16-Feb-01	66	56	39	52	15
Mar-01	12-Mar-01	NA	296	106	46	20
	14-Mar-01	55	229	135	33	5
	16-Mar-01	74	139	100	76	14
Apr-01	9-Apr-01	53	74	57	102	4
	11-Apr-01	51	104	94	60	NA*
	13-Apr-01	49	90	88	118	26
May-01	14-May-01	70	50	67	99	1
	16-May-01	75	51	86	212	ND
	18-May-01	120	148	184	353	11
Jun-01	11-Jun-01	54	27	60	376	3.2
	13-Jun-01	94	26	80	185	45
	15-Jun-01	50	20	87	144	35
Jul-01	9-Jul-01	48	34	73	151	23
	11-Jul-01	96	32	71	217	42
	13-Jul-01	57	16	72	330	40
Aug-01	13-Aug-01	51	41	53	142	22
	15-Aug-01	55	43	55	177	22
	17-Aug-01	62	107	88	230	24
Sep-01	10-Sep-01	39	49	31	44	19
	12-Sep-01	45	27	66	68	34
	14-Sep-01	80	35	43	163	26

NA=Not available
*=All water consumed in bioassay

TABLE 20. Dissolved Oxygen (mg/L) of Site Waters as Received at the BES Laboratory

MONTH	SAMPLE DATE	SITE LOCATION				
		B	C	D	F	DMC
Oct-00	16-Oct-00	10.4	7.6	7.5	9.5	10.0
	18-Oct-00	9.8	7.6	6.9	8.1	9.4
	20-Oct-00	9.8	7.4	6.8	8.3	9.0
Nov-00	13-Nov-00	13.1	10.0	9.9	10.9	10.7
	15-Nov-00	13.0	10.0	10.0	10.3	10.8
	17-Nov-00	9.8	10.6	9.3	9.7	9.9
Dec-00	11-Dec-00	10.8	9.8	10.3	9.8	10.6
	13-Dec-00	11.5	12.1	11.5	11.6	12.2
	15-Dec-00	11.3	10.3	10.3	10.1	10.8
Jan-01	8-Jan-01	11.3	10.6	10.5	10.1	10.1
	10-Jan-01	11.4	11.4	11.3	10.9	10.8
	12-Jan-01	11.7	11.9	12.0	12.1	11.4
Feb-01	12-Feb-01	10.1	9.9	9.7	9.2	9.1
	14-Feb-01	10.5	10.1	10.3	10.2	10.0
	16-Feb-01	10.5	10.1	10.5	9.8	10.7
Mar-01	12-Mar-01	11.0	9.3	9.5	9.4	10.0
	14-Mar-01	11.3	10.7	10.3	11.3	11.7
	16-Mar-01	10.9	9.1	9.8	10.0	9.7
Apr-01	9-Apr-01	10.9	10.4	10.4	10.3	9.8
	11-Apr-01	11.9	9.9	10.1	9.3	10.4
	13-Apr-01	12.2	10.3	10.8	8.8	10.6
May-01	14-May-01	9.6	9.9	9.6	8.2	9.4
	16-May-01	8.7	7.5	8.3	7.2	7.9
	18-May-01	10.3	8.0	9.8	8.0	10.0
Jun-01	11-Jun-01	10.5	9.7	8.8	8.5	9.0
	13-Jun-01	9.6	9.5	10.2	9.3	9.4
	15-Jun-01	12.3	9.2	9.9	8.4	8.9
Jul-01	9-Jul-01	9.6	9.6	9.4	8.4	8.8
	11-Jul-01	8.9	9.3	9.4	9.1	9.4
	13-Jul-01	10.6	10.6	10.8	10.9	9.5
Aug-01	13-Aug-01	9.6	9.0	8.0	9.0	10.1
	15-Aug-01	8.9	8.3	8.9	8.3	8.9
	17-Aug-01	11.8	10.2	9.3	9.2	8.7
Sep-01	10-Sep-01	10.1	8.6	8.7	8.5	9.1
	12-Sep-01	10.1	9.8	8.9	9.1	8.3
	14-Sep-01	10.4	8.2	8.2	8.4	9.3

TABLE 21. pH of Site Waters as Received at the BES Laboratory

MONTH	SAMPLE DATE	SITE LOCATION				
		B	C	D	F	DMC
Oct-00	16-Oct-00	8.4	7.7	7.7	7.8	7.7
	18-Oct-00	8.2	7.2	7.3	7.4	7.2
	20-Oct-00	8.2	7.7	7.6	7.7	7.7
Nov-00	13-Nov-00	8.0	7.7	7.7	7.6	7.8
	15-Nov-00	8.4	7.8	7.8	7.7	7.9
	17-Nov-00	8.2	7.9	7.9	7.9	7.9
Dec-00	11-Dec-00	7.1	7.2	7.3	7.3	7.3
	13-Dec-00	8.3	7.8	7.9	7.8	7.6
	15-Dec-00	7.5	7.5	7.5	7.4	7.5
Jan-01	8-Jan-01	7.8	7.9	7.8	7.7	7.8
	10-Jan-01	7.8	8.1	7.9	7.9	8.1
	12-Jan-01	7.5	7.7	7.7	7.7	7.8
Feb-01	12-Feb-01	8.2	8.2	8.2	8.1	8.2
	14-Feb-01	8.3	8.3	8.3	8.2	8.3
	16-Feb-01	7.8	8.0	7.9	7.9	8.3
Mar-01	12-Mar-01	8.3	8.1	8.2	7.8	8.0
	14-Mar-01	8.3	8.0	8.1	7.9	8.0
	16-Mar-01	8.5	8.2	8.2	8.1	8.1
Apr-01	9-Apr-01	8.6	8.5	8.5	7.9	8.0
	11-Apr-01	7.0	7.0	7.0	7.0	7.0
	13-Apr-01	8.6	8.3	8.4	7.8	7.9
May-01	14-May-01	8.4	8.2	8.3	7.8	8.2
	16-May-01	8.4	7.9	8.2	7.6	7.7
	18-May-01	8.4	7.8	8.3	7.8	7.8
Jun-01	11-Jun-01	8.5	8.5	8.5	7.9	8.1
	13-Jun-01	8.5	8.0	8.5	7.9	7.8
	15-Jun-01	8.6	8.0	8.5	7.9	8.0
Jul-01	9-Jul-01	8.4	8.1	8.4	7.9	8.0
	11-Jul-01	7.1	7.8	7.7	7.7	7.8
	13-Jul-01	8.0	8.0	8.5	7.8	8.1
Aug-01	13-Aug-01	8.4	8.1	7.9	8.1	8.4
	15-Aug-01	8.2	7.9	8.2	7.9	7.9
	17-Aug-01	8.2	7.9	8.1	7.8	7.9
Sep-01	10-Sep-01	8.5	7.9	8.1	7.8	7.9
	12-Sep-01	8.5	8.2	7.8	7.7	7.7
	14-Sep-01	8.6	7.8	8.1	7.9	8.0

TABLE 22. Salinity (ppt) of Site Waters as Received at the BES Laboratory

MONTH	SAMPLE DATE	SITE LOCATION				
		B	C	D	F	DMC
Oct-00	16-Oct-00	1.5	ND	0.5	0.5	0.1
	18-Oct-00	1.2	0.2	0.3	0.5	0.1
	20-Oct-00	1.5	0.3	0.5	0.8	0.2
Nov-00	13-Nov-00	1.7	0.6	0.7	0.6	0.3
	15-Nov-00	1.8	0.7	0.8	0.7	0.3
	17-Nov-00	5.0	5.0	5.0	5.0	0.1
Dec-00	11-Dec-00	2.0	1.0	1.0	1.0	ND
	13-Dec-00	2.0	1.0	1.0	ND	ND
	15-Dec-00	2.0	1.0	1.0	1.0	ND
Jan-01	8-Jan-01	2.0	1.0	2.0	1.0	1.0
	10-Jan-01	4.0	2.0	2.0	1.0	1.0
	12-Jan-01	3.0	2.0	2.0	1.0	1.0
Feb-01	12-Feb-01	2.4	0.9	1.3	0.7	0.3
	14-Feb-01	2.4	0.9	1.4	0.7	0.2
	16-Feb-01	2.4	1.0	1.4	0.8	0.2
Mar-01	12-Mar-01	3.0	1.5	1.4	0.8	0.3
	14-Mar-01	3.0	1.5	1.5	0.8	0.3
	16-Mar-01	3.0	1.2	1.6	0.9	0.3
Apr-01	9-Apr-01	27.0	1.2	2.2	0.7	0.4
	11-Apr-01	2.7	0.9	1.7	0.8	0.2
	13-Apr-01	2.9	0.9	1.7	0.8	0.2
May-01	14-May-01	2.7	0.7	1.7	0.7	0.3
	16-May-01	2.3	0.7	1.4	0.5	0.3
	18-May-01	2.0	1.0	2.0	0.3	0.3
Jun-01	11-Jun-01	2.6	1.0	2.2	0.8	0.3
	13-Jun-01	2.5	1.6	2.4	0.7	0.2
	15-Jun-01	2.4	1.7	2.4	0.6	0.4
Jul-01	9-Jul-01	0.2	1.2	1.9	0.6	0.2
	11-Jul-01	0.2	1.2	1.8	0.6	0.2
	13-Jul-01	0.2	1.3	2.0	0.5	0.2
Aug-01	13-Aug-01	1.9	1.3	0.6	0.3	2.0
	15-Aug-01	3.6	2.1	1.9	0.6	0.3
	17-Aug-01	3.5	0.8	1.7	0.6	0.3
Sep-01	10-Sep-01	2.2	0.5	1.2	0.7	0.3
	12-Sep-01	2.2	0.4	1.2	0.8	0.5
	14-Sep-01	1.8	0.7	1.3	0.8	0.4

ND=Not Detected

TABLE 23. Alkalinity (as mg/L $CaCO_3$) of Site Waters as Received at the BES Laboratory

MONTH	SAMPLE DATE	SITE LOCATION				
		B	C	D	F	DMC
Oct-00	16-Oct-00	192	182	182	180	98
	18-Oct-00	180	170	176	160	88
	20-Oct-00	172	188	192	180	84
Nov-00	13-Nov-00	96	202	180	185	70
	15-Nov-00	96	236	222	194	82
	17-Nov-00	80	182	232	228	484
Dec-00	11-Dec-00	252	372	240	242	90
	13-Dec-00	222	212	218	160	80
	15-Dec-00	216	214	214	192	80
Jan-01	8-Jan-01	206	228	234	270	96
	10-Jan-01	190	250	224	162	92
	12-Jan-01	188	214	204	158	122
Feb-01	12-Feb-01	166	254	348	146	98
	14-Feb-01	176	258	184	160	80
	16-Feb-01	176	244	230	170	84
Mar-01	12-Mar-01	214	256	258	180	110
	14-Mar-01	196	270	262	192	100
	16-Mar-01	178	310	286	190	86
Apr-01	9-Apr-01	150	278	202	172	116
	11-Apr-01	152	232	206	184	116
	13-Apr-01	164	222	200	192	84
May-01	14-May-01	156	162	166	158	78
	16-May-01	156	320	158	134	102
	18-May-01	404	220	180	160	98
Jun-01	11-Jun-01	156	220	356	164	104
	13-Jun-01	162	250	156	166	98
	15-Jun-01	152	280	150	192	102
Jul-01	9-Jul-01	166	32	178	162	94
	11-Jul-01	152	28	172	148	78
	13-Jul-01	76	246	156	144	78
Aug-01	13-Aug-01	178	218	156	174	94
	15-Aug-01	152	300	154	144	104
	17-Aug-01	178	212	166	180	90
Sep-01	10-Sep-01	136	146	156	174	94
	12-Sep-01	64	74	154	144	104
	14-Sep-01	84	164	166	180	90

NA=Not Available

TABLE 24. Hardness (as mg/L $CaCO_3$) of Site Waters as Received at the BES Laboratory

	SAMPLE	SITE LOCATION				
MONTH	DATE	B	C	D	F	DMC
Oct-00	16-Oct-00	984	182	288	268	122
	18-Oct-00	996	258	336	336	184
	20-Oct-00	868	186	290	330	96
Nov-00	13-Nov-00	200	216	338	284	86
	15-Nov-00	200	190	176	180	172
	17-Nov-00	194	652	216	160	280
Dec-00	11-Dec-00	504	350	216	216	92
	13-Dec-00	478	194	200	146	118
	15-Dec-00	1000	320	444	190	118
Jan-01	8-Jan-01	986	384	516	168	142
	10-Jan-01	1240	344	454	300	114
	12-Jan-01	658	300	406	298	180
Feb-01	12-Feb-01	1000	324	598	260	100
	14-Feb-01	960	378	320	220	90
	16-Feb-01	808	300	528	240	90
Mar-01	12-Mar-01	1278	470	526	346	136
	14-Mar-01	184	284	242	194	106
	16-Mar-01	1408	378	612	340	100
Apr-01	9-Apr-01	1238	156	922	292	188
	11-Apr-01	136	240	182	172	154
	13-Apr-01	400	290	414	280	82
May-01	14-May-01	1160	278	706	290	124
	16-May-01	996	284	544	306	114
	18-May-01	1080	354	600	244	154
Jun-01	11-Jun-01	1082	386	902	308	220
	13-Jun-01	1188	622	780	282	180
	15-Jun-01	974	576	930	270	166
Jul-01	9-Jul-01	832	444	770	234	126
	11-Jul-01	798	108	418	222	108
	13-Jul-01	86	458	776	230	82
Aug-01	13-Aug-01	772	456	802	258	116
	15-Aug-01	840	596	816	260	148
	17-Aug-01	848	294	748	272	178
Sep-01	10-Sep-01	906	228	802	258	116
	12-Sep-01	1064	174	816	260	148
	14-Sep-01	750	266	748	272	178

NA=Not Available

TABLE 25. Temperature (°C) of Site Waters as Received at the BES Laboratory

MONTH	SAMPLE DATE	SITE LOCATION				
		B	C	D	F	DMC
Oct-00	16-Oct-00	12.0	5.0	6.0	5.0	12.0
	18-Oct-00	6.2	7.1	5.9	6.2	6.2
	20-Oct-00	4.0	5.0	5.0	9.0	11.0
Nov-00	13-Nov-00	4.3	4.3	3.6	3.8	7.0
	15-Nov-00	4.0	4.0	4.0	4.0	4.0
	17-Nov-00	6.0	6.0	6.0	6.0	6.0
Dec-00	11-Dec-00	8.0	10.0	10.8	10.0	10.0
	13-Dec-00	2.3	3.4	2.8	3.2	3.0
	15-Dec-00	2.0	2.0	2.0	2.0	2.0
Jan-01	8-Jan-01	9.2	9.4	8.2	8.7	8.4
	10-Jan-01	10.0	8.9	9.0	9.0	6.0
	12-Jan-01	5.5	5.5	5.5	5.5	8.5
Feb-01	12-Feb-01	9.1	9.2	8.7	9.5	9.6
	14-Feb-01	2.7	2.8	3.2	3.3	3.3
	16-Feb-01	3.2	2.5	2.9	4.6	3.2
Mar-01	12-Mar-01	16.3	10.0	15.0	15.7	16.0
	14-Mar-01	5.0	6.5	11.5	5.5	5.0
	16-Mar-01	6.0	3.0	4.2	4.5	6.0
Apr-01	9-Apr-01	12.0	13.1	11.0	10.9	13.1
	11-Apr-01	3.0	3.9	4.0	3.5	3.9
	13-Apr-01	6.5	9.1	5.3	6.0	6.1
May-01	14-May-01	15.0	8.0	7.0	13.5	18.0
	16-May-01	4.9	5.0	5.0	4.9	11.8
	18-May-01	6.5	8.7	6.5	9.0	8.0
Jun-01	11-Jun-01	14.5	15.1	21.3	17.0	16.9
	13-Jun-01	15.4	8.9	6.3	6.2	3.9
	15-Jun-01	6.0	9.5	10.2	10.0	10.1
Jul-01	9-Jul-01	19.7	17.9	22.5	24.0	22.2
	11-Jul-01	15.0	18.0	15.0	15.0	15.0
	13-Jul-01	6.7	5.7	11.5	8.3	11.0
Aug-01	13-Aug-01	23.7	22.8	24.0	21.7	21.8
	15-Aug-01	14.9	13.6	13.7	13.9	13.9
	17-Aug-01	10.3	12.5	12.0	11.9	10.5
Sep-01	10-Sep-01	18.0	17.2	17.4	14.6	16.7
	12-Sep-01	8.0	8.5	8.5	9.1	8.5
	14-Sep-01	7.5	14.8	6.4	7.4	8.4

TABLE 26. Ammonia (ppm as Nitrogen) of Site Waters as Received at the BES Laboratory

MONTH	SAMPLE DATE	SITE LOCATION				
		B	C	D	F	DMC
Oct-00	16-Oct-00	ND	1.22	0.37	1.22	ND
	18-Oct-00	0.06	ND	ND	0.12	ND
	20-Oct-00	0.61	0.48	0.24	1.10	ND
Nov-00	13-Nov-00	0.12	0.49	0.04	0.61	0.24
	15-Nov-00	ND	ND	ND	ND	ND
	17-Nov-00	ND	ND	ND	ND	ND
Dec-00	11-Dec-00	ND	ND	ND	ND	ND
	13-Dec-00	0.12	ND	0.31	0.37	0.12
	15-Dec-00	ND	0.37	0.37	0.37	0.12
Jan-01	8-Jan-01	1.59	0.18	0.18	1.59	ND
	10-Jan-01	3.05	0.24	0.18	0.49	ND
	12-Jan-01	0.73	0.24	0.37	0.37	ND
Feb-01	12-Feb-01	0.10	0.30	0.50	0.20	0.60
	14-Feb-01	1.00	0.40	0.40	0.20	0.60
	16-Feb-01	3.10	0.30	0.20	0.20	0.50
Mar-01	12-Mar-01	ND	ND	0.10	ND	ND
	14-Mar-01	ND	0.40	0.10	ND	ND
	16-Mar-01	7.40	0.10	ND	ND	0.10
Apr-01	9-Apr-01	1.46	0.49	2.20	19.52	ND
	11-Apr-01	0.49	0.37	2.20	19.52	ND
	13-Apr-01	1.34	0.15	0.24	0.18	0.33
May-01	14-May-01	0.40	0.30	0.30	0.80	0.20
	16-May-01	0.40	0.30	0.30	0.80	0.20
	18-May-01	0.30	0.20	0.30	0.60	0.20
Jun-01	11-Jun-01	ND	0.10	0.10	0.40	0.10
	13-Jun-01	ND	ND	0.20	0.30	0.20
	15-Jun-01	0.20	ND	0.30	0.60	0.10
Jul-01	9-Jul-01	0.10	ND	0.10	0.60	0.10
	11-Jul-01	ND	ND	ND	0.30	ND
	13-Jul-01	0.10	0.10	0.10	0.40	0.10
Aug-01	13-Aug-01	0.20	0.20	0.20	0.30	0.20
	15-Aug-01	0.30	ND	0.30	0.50	0.30
	17-Aug-01	0.40	0.40	0.20	0.60	0.20
Sep-01	10-Sep-01	0.20	0.30	0.20	0.30	0.20
	12-Sep-01	0.50	0.30	0.30	0.50	0.30
	14-Sep-01	0.20	0.40	0.20	0.60	0.20

NA=Not Available
ND=Not Detected

TABLE 27. Total Chlorine (mg/L) of Site Waters as Received at the BES Laboratory

MONTH	SAMPLE DATE	SITE LOCATION				
		B	C	D	F	DMC
Oct-00	16-Oct-00	1.00	1.00	0.30	1.00	0.20
	18-Oct-00	0.30	0.30	0.30	ND	0.10
	20-Oct-00	0.30	3.00	0.40	0.20	0.30
Nov-00	13-Nov-00	0.20	ND	0.10	0.10	ND
	15-Nov-00	0.30	0.20	0.20	0.20	0.40
	17-Nov-00	ND	0.80	0.40	0.30	0.20
Dec-00	11-Dec-00	0.20	0.15	0.05	0.05	ND
	13-Dec-00	0.10	0.10	0.15	0.10	ND
	15-Dec-00	0.15	0.10	0.15	0.10	ND
Jan-01	8-Jan-01	0.40	0.40	0.30	0.30	0.20
	10-Jan-01	0.30	0.10	0.10	0.10	ND
	12-Jan-01	0.20	0.20	0.10	0.20	0.50
Feb-01	12-Feb-01	0.10	0.10	0.10	0.10	ND
	14-Feb-01	0.10	0.20	0.20	0.10	ND
	16-Feb-01	ND	ND	ND	ND	ND
Mar-01	12-Mar-01	0.10	0.10	0.10	ND	ND
	14-Mar-01	ND	0.20	0.10	ND	0.10
	16-Mar-01	ND	0.10	0.10	ND	ND
Apr-01	9-Apr-01	ND	0.15	0.20	ND	ND
	11-Apr-01	ND	0.10	0.15	ND	ND
	13-Apr-01	0.13	0.01	0.10	0.05	0.05
May-01	14-May-01	0.20	0.20	0.30	0.10	0.10
	16-May-01	0.20	0.20	0.30	0.10	0.10
	18-May-01	0.30	0.30	0.40	0.30	0.10
Jun-01	11-Jun-01	0.20	0.50	1.50	0.10	ND
	13-Jun-01	0.10	0.40	0.50	0.40	0.30
	15-Jun-01	0.20	0.50	0.70	0.40	0.30
Jul-01	9-Jul-01	0.20	0.10	0.30	0.10	ND
	11-Jul-01	0.20	0.10	0.20	ND	0.10
	13-Jul-01	0.20	ND	0.20	0.20	0.10
Aug-01	13-Aug-01	0.20	0.10	0.30	0.10	ND
	15-Aug-01	0.10	0.10	0.20	0.20	0.10
	17-Aug-01	0.30	0.30	0.30	0.20	0.20
Sep-01	10-Sep-01	0.20	0.20	0.30	0.10	ND
	12-Sep-01	0.10	ND	0.20	0.20	0.10
	14-Sep-01	0.20	0.20	0.30	0.20	0.20

NA=Not Available
ND=Not Detected
* =Chlorine level measured at 2.5 mg/l, which is believed to be erroneous data

GRASSLAND BYPASS PROJECT

9

Sediment Monitoring

Tim McLaughlin,
U.S. Bureau of Reclamation

Purpose

Sediment monitoring for the Grassland Bypass Project (Project) focuses on measuring selenium and organic carbon parameters in the San Luis Drain (SLD), Mud Slough, and Salt Slough. The purpose of the monitoring is to assess the selenium concentrations in the sediment samples over the 5-year life of the Project. The measurements within the SLD provide selenium concentration estimates for comparison with California Department of Health Services' hazardous waste criterion. The measurements in Mud and Salt Sloughs provide selenium concentrations for comparison with USFWS thresholds for ecological risk.

Sampling Locations

Sampling locations for sediment monitoring (Stations A, B, C, D, E, F, and I) are defined in the Project's Compliance Monitoring Plan and depicted in Figure 2, Chapter 1. At the request of USFWS, sediment monitoring within Salt Slough (Station F) was changed from Lander Avenue to a location upstream of the San Luis National Wildlife Refuge used by USFWS for biota monitoring. This change was made for the September 1997 sampling event. Station I was changed at the end of the 5th year, water year 2001, and is now located in backwaters of Mud Slough, relatively close to the old station.

Sampling Frequency

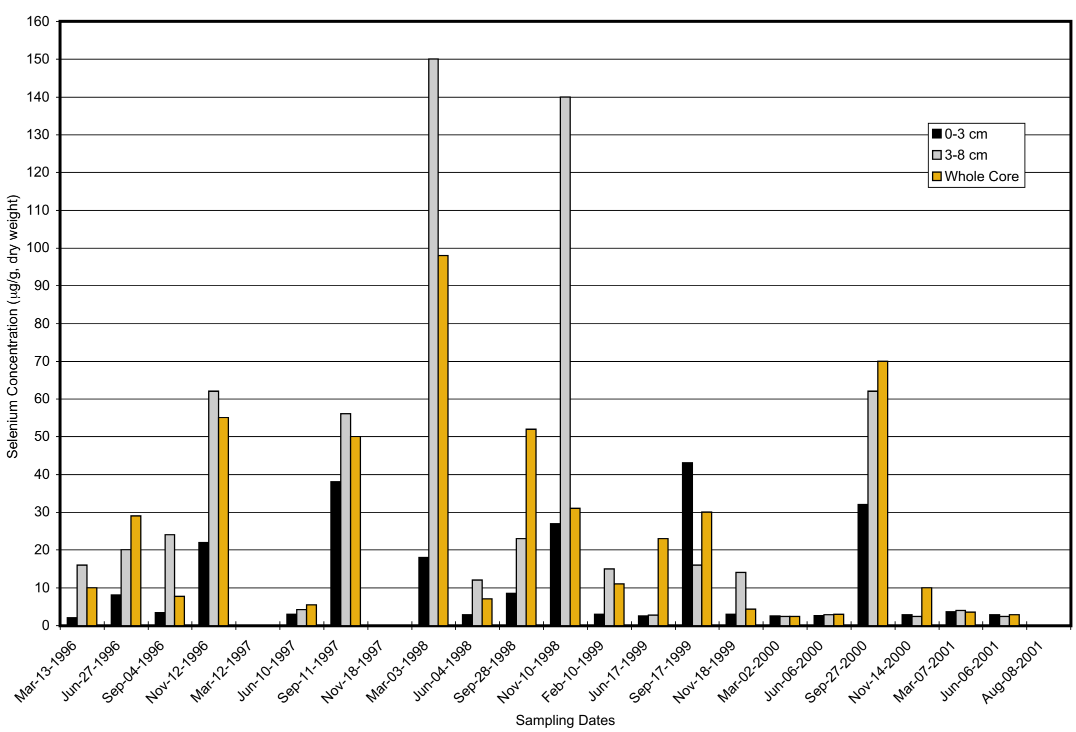
Quarterly sampling periods are November, March, June, and September for each of the water years. The sampling periods correspond with the biota sampling events of the USFWS.

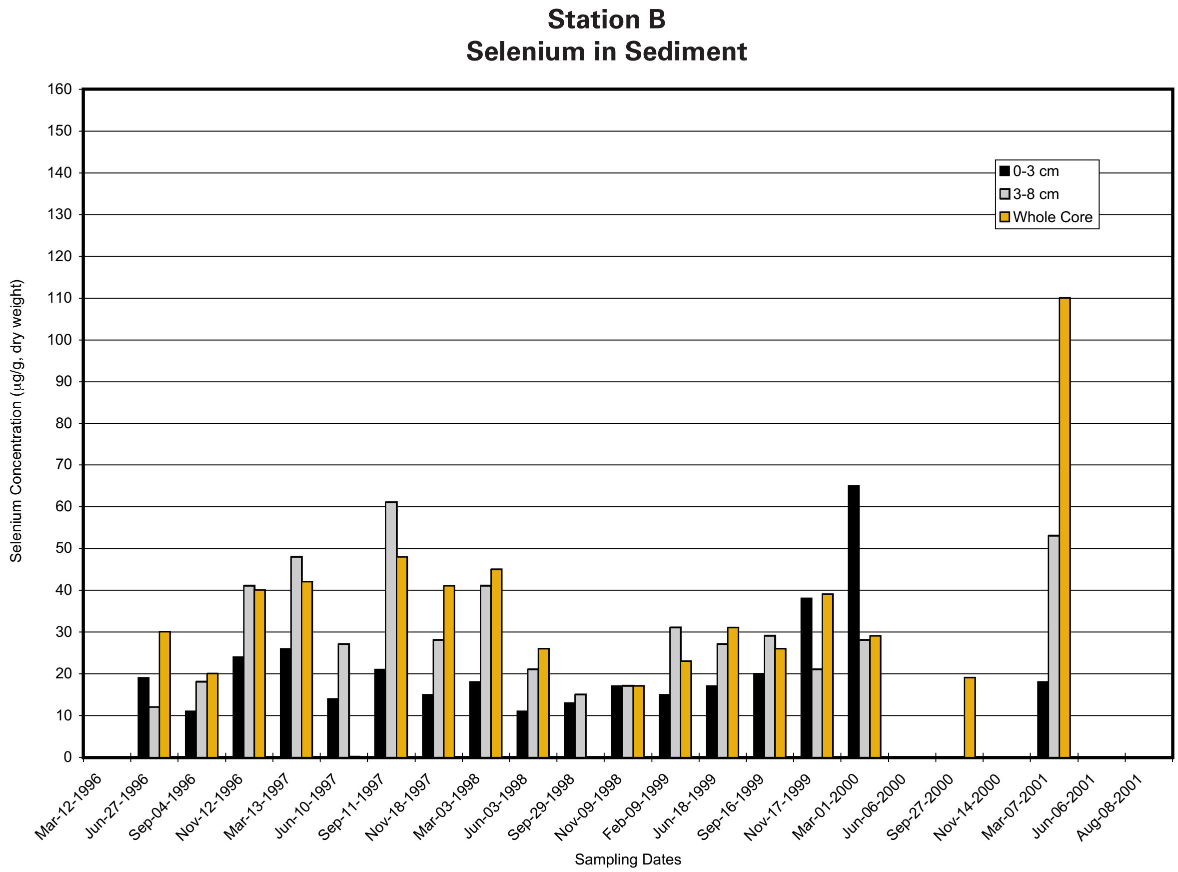
Sampling frequency includes quarterly measurements for Stations A and B (San Luis Drain), Station F (Salt Slough), and Stations C, D, I, and E (Mud Slough). Annual measurements are also made for 10 locations in the SLD.

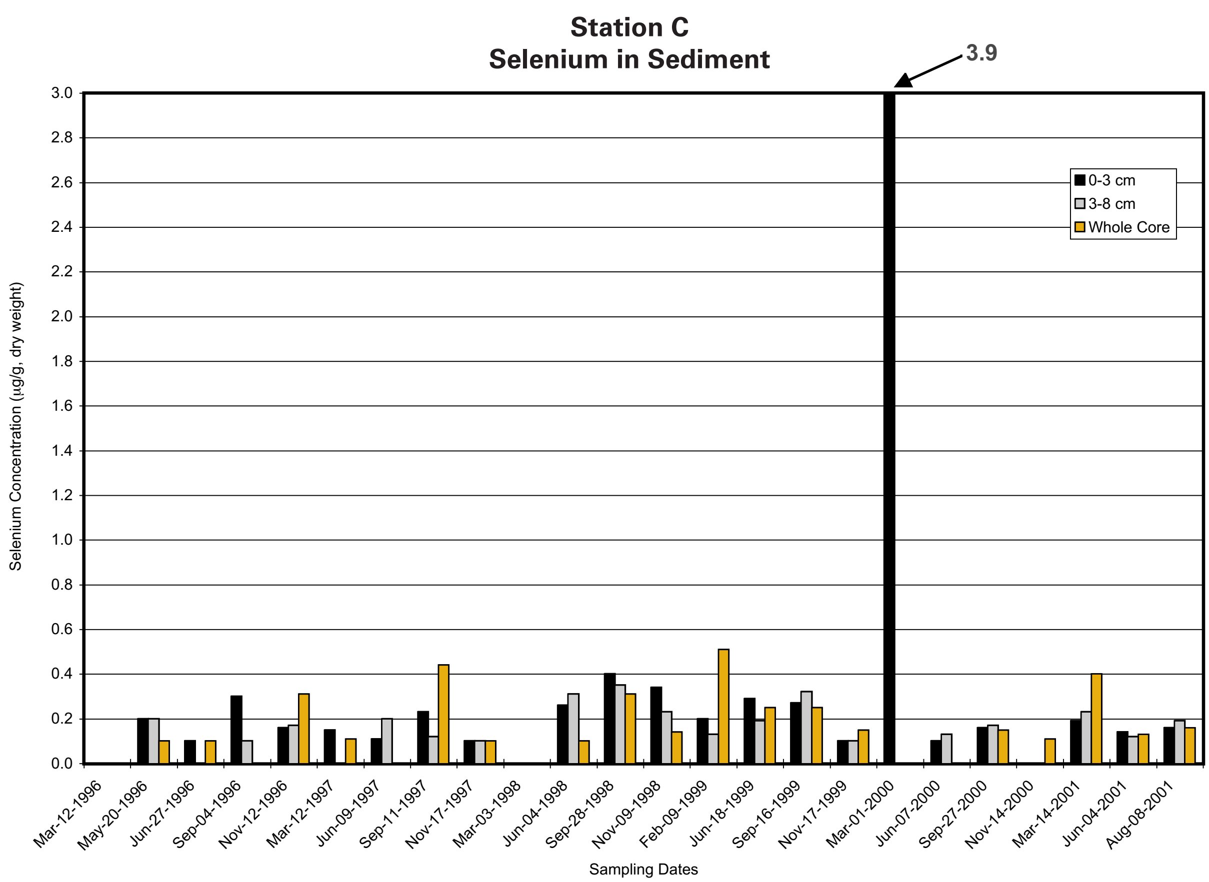
Sampling Methods

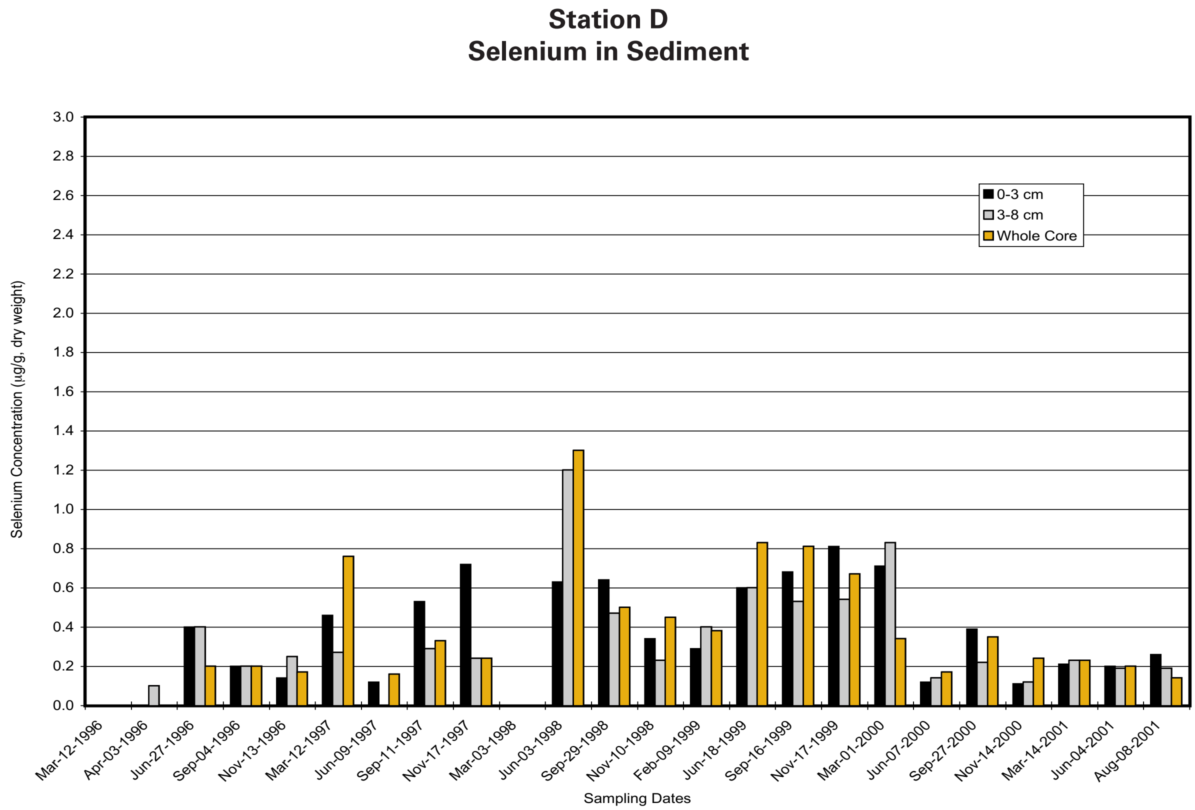
Sediment samples are collected using an acrylic coring device (4.5 cm diameter, 38 cm internal length). After collecting the sediment, sections of the core, 0-3 cm and 3-8 cm, are slowly extruded using a non-metallic internal pushing device and placed in distinct quart size mixing bowls. An additional sample is collected near the same spot for the whole-core sample and placed into a third mixing bowl. The process is continued until three samples along a transect are completed. Material from the 2nd and 3rd samples are placed in the corresponding 0-3 cm, 3-8 cm and whole-core mixing bowls containing the 1st samples. Each of the mixing bowls contain material from the transect. The 0-3 cm, 3-8 cm, and whole core samples are then mixed well in their mixing

Station A
Selenium in Sediment




Station B
Selenium in Sediment
Selenium Concentration (µg/g, dry weight)
Sampling Dates
0-3 cm
3-8 cm
Whole Core
Mar-12-1996
Jun-27-1996
Sep-04-1996
Nov-12-1996
Mar-13-1997
Jun-10-1997
Sep-11-1997
Nov-18-1997
Mar-03-1998
Jun-03-1998
Sep-29-1998
Nov-09-1998
Feb-09-1999
Jun-18-1999
Sep-16-1999
Nov-17-1999
Mar-01-2000
Jun-06-2000
Sep-27-2000
Nov-14-2000
Mar-07-2001
Jun-06-2001
Aug-08-2001


Station C
Selenium in Sediment
3.9
Selenium Concentration (µg/g, dry weight)
Sampling Dates
0-3 cm
3-8 cm
Whole Core
Mar-12-1996
May-20-1996
Jun-27-1996
Sep-04-1996
Nov-12-1996
Mar-12-1997
Jun-09-1997
Sep-11-1997
Nov-17-1997
Mar-03-1998
Jun-04-1998
Sep-28-1998
Nov-09-1998
Feb-09-1999
Jun-18-1999
Sep-16-1999
Nov-17-1999
Mar-01-2000
Jun-07-2000
Sep-27-2000
Nov-14-2000
Mar-14-2001
Jun-04-2001
Aug-08-2001



bowls in a manner similar to kneading bread. The mixing objective is to obtain one homogeneous sample in each of the bowls. Composited samples are then placed in a wide-mouth polyethylene container and stored in an ice chest at 4°C.

Results

Table 1 shows information from all of the stations describing each sampling period, each core partition, and each parameter. All values are based on dry weight. Figures 1 through 7 depict the selenium information with the help of bar charts. Further discussion is limited to selenium concentrations only. Data are compared to the following:

Guidelines (for Mud and Salt Slough):

• the recommended ecological risk guidelines for selenium concentrations in sediment (Table 1, Chapter 7) are as follows: "no effect" - less than 2 µg/g, dry weight, "level of concern" - 2 to 4 µg/g, dry weight, and "toxicity" - greater than 4 µg/g, dry weight.

Criteria (for the San Luis Drain):

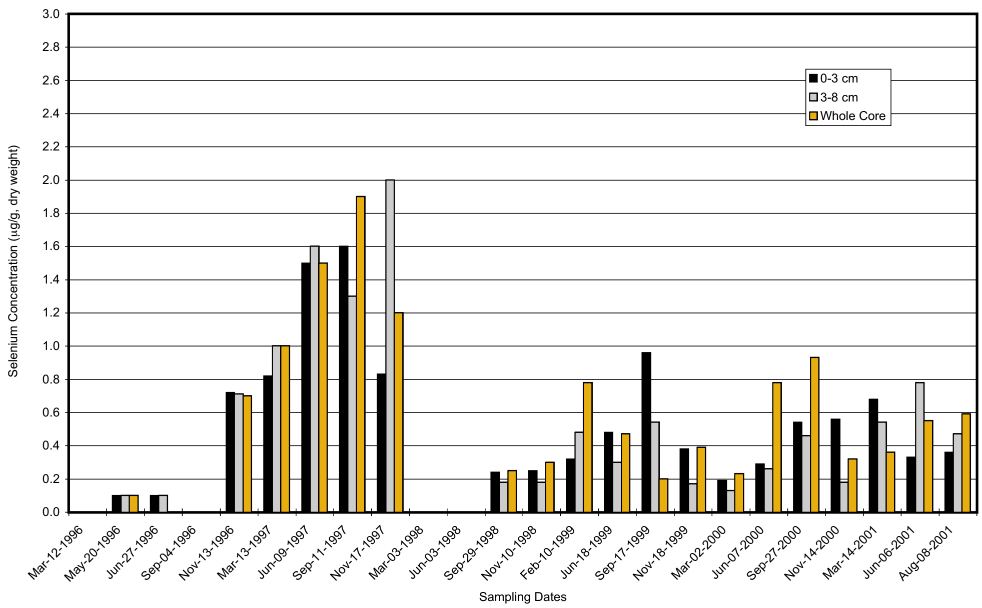
• the California Department of Health Services established a criteria for selenium concentration in sediment of 100 µg/g wet weight. Should the selenium concentrations in sediment from the SLD exceed this value, material dredged from the drain would have to be deposited in a hazardous waste site.

Ecological risk: Mud and Salt Slough

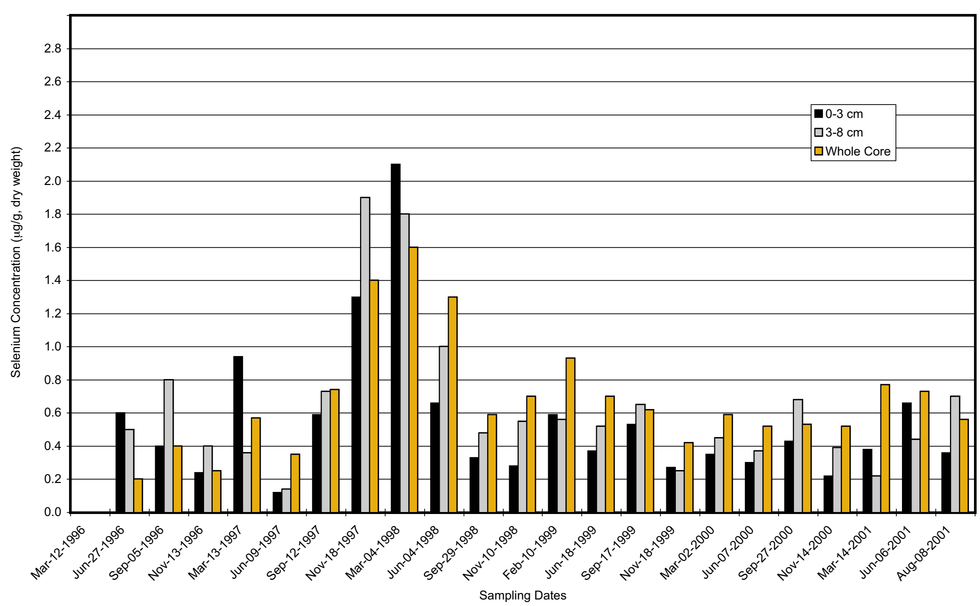
With one exception, selenium concentrations in the sediment from within-slough sampling stations (C, D, I, E, and F) were below the 2.0 µg/g ("no effect level") for the 5th year, last 4 quarterly sampling periods. The November 2000 samples for Station I were above 2.0 µg/g level.

Recapping the 5-year project, the following occurred: one observation was above 2.0 µg/g (no effect range) in Station F (Salt Slough), one observation was above 2.0 µg/g in Station C (Mud Slough), no observations were above 2.0 µg/g in Station D (Mud Slough), eight observations were above 2.0 µg/g in Station I (Mud Slough), and no observations were above 2.0 µg/g in Station E (Mud Slough).

Station E
Selenium in Sediment



Station F
Selenium in Sediment

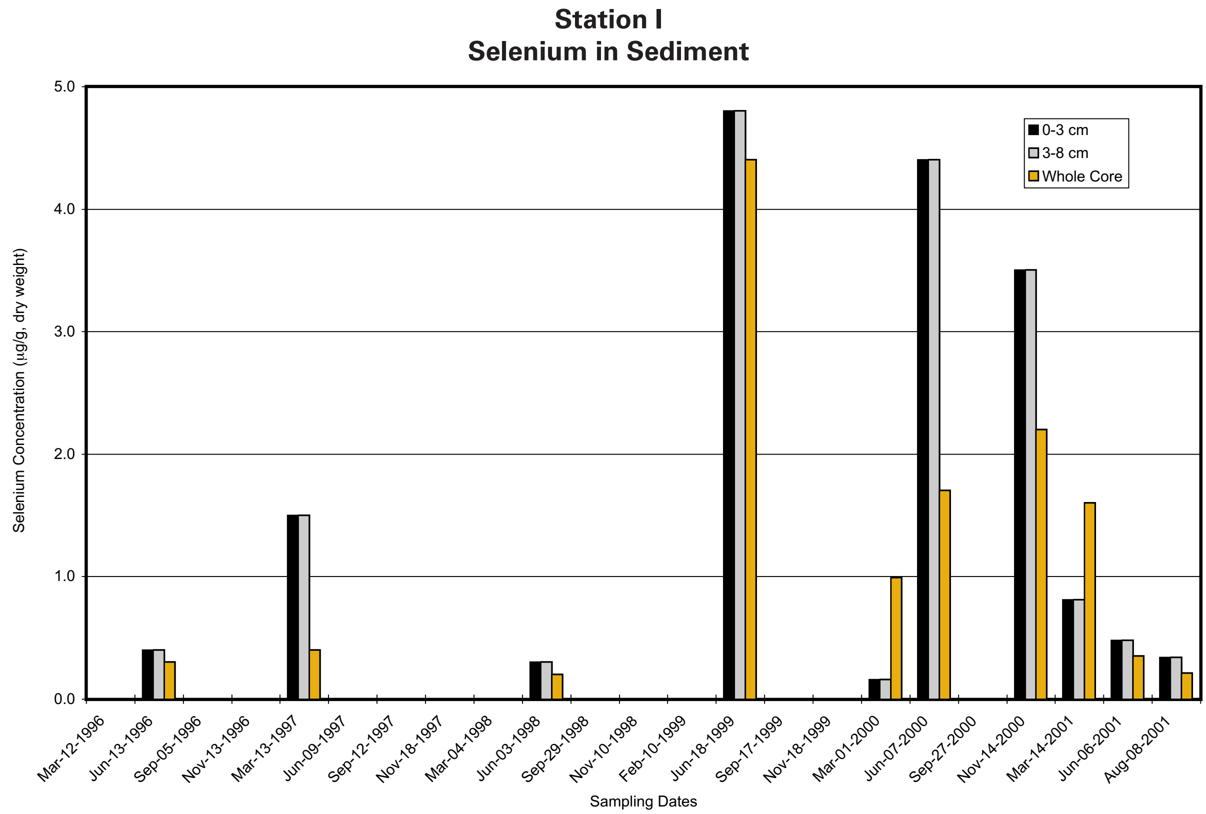


Hazardous waste material criteria: San Luis Drain

Results from the 5-year project for Stations A and B are depicted in figures 1 and 2. For the entire period of record, the range of selenium concentration values from Station A were 2.0 - 150 µg/g, dry weight. For Station B, the ranges were .11 - 110 µg/g, dry weight. Similar variability was observed in the other 10 locations within the SLD. The highest selenium values, dry weight, from the SLD were 150 µg/g, 140 µg/g, 100 µg/g, and 100 µg/g. To make the comparison for hazardous waste criteria, the data needs to be converted to a wet weight basis. The formula used to make the comparison is as follows:

wet weight = (dry weight µg/g) * (1.0 - percent moisture/100.0).

The conversion for the above 4 highest values provides wet weight concentrations of 55 µg/g, 56 µg/g, 40 µg/l, and 38 µg/g, respectively. These concentrations



from the SLD are well below the 100 µg/g wet weight hazardous material criterion established by the California Department of Health Services.

Quality Control

Laboratory Precision

Duplicate samples are two discrete samples (aliquots) taken from the same parent material and analyzed independently. The results, which should be similar, demonstrate the laboratory's ability to achieve consistent results. GBP Monitoring Program Quality Assurance protocol requires laboratory re-analysis if there is a relative percent difference (RPD) between duplicates greater than 35%. Table 2 shows results of the duplicate analyses. During the 5-year project, 7 of the 60 duplicate samples differed by more than 35%. In all but one case, the re-analyzed results were similar to the original. Results of duplicate samples collected on June 24, 2001 at Station D were .21 µg/g and 1.5 µg/g, with an RPD of 150.9. Re-analysis yielded values of .20 µg/g and .20 µg/g, respectively.

Sample Variability

To examine sample variability, two or more samples are collected from the same station during the same sampling event. Table 3 presents all replicate samples collected over the 4 years of the project. Of the 18 replicate samples analyzed, 8 exceeded the QA objective of an RPD <= 35%. No replicated samples were collected during the final year of the Project.

The purpose of the replicate sampling in the San Luis Drain was to demonstrate the variability of selenium concentrations in sediment within the SLD. With 8 out of the 18 samples exceeding the 35 % criteria, the conclusions would be that the selenium in sediments are not necessarily evenly distributed within the SLD. That conclusion led to a new sampling scheme for sampling sediments in the SLD for Phase II of the project. The annual sampling program is now locating the samples based upon the amount of sediment within each reach of the SLD (chapter 10).

Table 1. Sediment Monitoring Results

Sampling Date	Selenium Concentration			Organic Carbon			Percent Moisture		
	0-3 cm	3-8 cm	Whole Core	0-3 cm	3-8 cm	Whole Core	0-3 cm	3-8 cm	Whole Core
	ug/g, dry weight	ug/g, dry weight	ug/g, dry weight	%	%	%	%	%	%
Station A									
Mar-13-1996	2.0	16	10	3.9	3.6	3.4	83.3	79.1	80.5
Jun-27-1996	8.0	20	29	4.33	5.01	2.96	83.8	78.30	71.2
Sep-04-1996	3.4	24	7.7	4.35	2.72	4.10	81.2	73.3	76.0
Nov-12-1996	22	62	55	2.92	3.10	3.72	*	*	*
Mar-12-1997	NT	NT	NT	NT	NT	NT	NT	NT	NT
Jun-10-1997	2.9	4.2	5.4	0.89	1.55	2.10	55.0	58.0	62.0
Sep-11-1997	38	56	50	1.52	2.18	1.95	70.6	75.7	70.2
Nov-18-1997	NT	NT	NT	NT	NT	NT	NT	NT	NT
Mar-03-1998	18	150	98	1.21	2.89	2.28	52.9	63.3	65.0
Jun-04-1998	2.8	12	7.0	0.58	1.58	1.03	35.2	54.9	50.0
Sep-28-1998	8.5	23	52	1.06	1.17	2.25	55.0	55.3	67.9
Nov-10-1998	27	140	31	1.55	2.61	1.43	71.0	60.1	59.6
Feb-10-1999	3.0	15	11	1.32	1.45	1.10	69.3	65.0	59.1
Jun-17-1999	2.5	2.7	23	1.03	1.01	1.34	49.6	52.9	56.3
Sep-17-1999	43	16	30	1.11	1.23	2.05	61.4	59.5	68.4
Nov-18-1999	2.9	14	4.3	0.80	1.36	0.93	55.6	59.1	53.3
Mar-02-2000	2.5	2.4	2.4	0.71	0.83	0.98	47.3	48.3	51.4
Jun-06-2000	2.6	2.8	3.0	0.92	0.86	0.87	43.3	44.4	44.1
Sep-27-2000	32	62	70	2.99	2.32	1.81	73.1	70.7	67.9
Nov-14-2000	2.8	2.4	10	1.23	0.87	1.76	54.8	45.4	57.9
Mar-07-2001	3.6	4.0	3.5	1.13	1.45	1.21	43.5	45.3	48.1
Jun-06-2001	2.8	2.4	2.8	1.07	0.8	0.79	45.0	44.4	46.0
Aug-08-2001	NT	NT	NT	NT	NT	NT	NT	NT	NT
Station B									
Mar-12-1996	NT	NT	NT	NT	NT	NT	NT	NT	NT
Jun-27-1996	19	12	30	2.70	2.81	2.15	64.7	59.9	59.0
Sep-04-1996	11	18	20	3.85	3.75	2.08	66.5	61.7	51.2
Nov-12-1996	24	41	40	1.97	1.89	3.45	*	*	*
Mar-13-1997	26	48	42	2.49	2.36	2.66	*	*	*
Jun-10-1997	14	27	0.11	2.14	2.95	0.07	40.0	49.0	58.0
Sep-11-1997	21	61	48	2.39	2.82	1.84	65.9	61.4	53.8
Nov-18-1997	15	28	41	1.62	1.86	1.73	53.8	44.2	50.2
Mar-03-1998	18	41	45	1.46	1.70	1.73	50.8	51.4	54.3
Jun-03-1998	11	21	26	0.85	1.51	1.09	46.6	54.0	46.1
Sep-29-1998	13	15	NT	1.51	1.64	NT	85.9	79.5	NT
Nov-09-1998	17	17	17	1.68	1.74	1.76	73.2	80.8	56.7
Feb-09-1999	15	31	23	0.94	1.93	1.87	61.3	60.9	72.7
Jun-18-1999	17	27	31	1.45	1.84	1.28	56.1	61.4	47.1
Sep-16-1999	20	29	26	1.65	2.03	1.57	51.7	54.7	59.2
Nov-17-1999	38	21	39	2.23	1.96	1.92	58.8	55.6	55.9
Mar-01-2000	65	28	29	1.8	0.99	1.32	59.1	53.8	43.2
Jun-06-2000	NT	NT	NT	NT	NT	NT	NT	NT	NT
Sep-27-2000	NT	NT	19	NT	NT	0.62	NT	NT	40.9
Nov-14-2000	NT	NT	NT	NT	NT	NT	NT	NT	NT
Mar-07-2001	18	53	110	0.67	1.86	2.89	31.5	49.6	59.4
Jun-06-2001	NT	NT	NT	NT	NT	NT	NT	NT	NT
Aug-08-2001	NT	NT	NT	NT	NT	NT	NT	NT	NT

Table 1 (cont). Sediment Monitoring Results

Sampling Date	Selenium Concentration			Organic Carbon			Percent Moisture		
	0-3 cm	3-8 cm	Whole Core	0-3 cm	3-8 cm	Whole Core	0-3 cm	3-8 cm	Whole Core
	ug/g, dry weight	ug/g, dry weight	ug/g, dry weight	%	%	%	%	%	%
Station C	NT	NT	NT	NT	NT	NT	NT	NT	NT
Mar-12-1996	0.2	0.2	0.1	0.8	0.6	0.6	38.5	39.4	36.6
May-20-1996	0.1	<0.10	0.1	0.49	0.40	0.14	34.0	30.0	25.2
Jun-27-1996	0.3	0.1	<0.10	0.38	0.53	0.53	33.1	36.5	40.6
Sep-04-1996	0.16	0.17	0.31	0.26	0.28	0.95	*	*	*
Nov-12-1996	0.15	<0.10	0.11	0.35	0.28	0.68	*	*	*
Mar-12-1997	0.11	0.20	<0.10	0.31	0.27	0.16	30.0	53.0	28.0
Jun-09-1997	0.23	0.12	0.44	0.41	0.19	0.92	32.7	24.3	38.6
Sep-11-1997	0.10	0.10	0.10	0.27	0.18	0.32	28.7	26.7	65.5
Nov-17-1997	NT	NT	NT	NT	NT	NT	NT	NT	NT
Mar-03-1998	0.26	0.31	0.10	0.58	0.62	0.33	35.3	29.4	49.2
Jun-04-1998	0.40	0.35	0.31	0.77	0.70	0.53	40.7	39.1	35.2
Sep-28-1998	0.34	0.23	0.14	0.55	0.66	0.33	35.1	32.1	30.7
Nov-09-1998	0.20	0.13	0.51	0.28	0.21	0.85	33.5	30.7	34.2
Feb-09-1999	0.29	0.19	0.25	0.40	0.22	0.20	34.3	25.3	28.1
Jun-18-1999	0.27	0.32	0.25	0.60	0.67	0.54	36.9	35.5	
Sep-16-1999	0.10	0.10	0.15	0.15	0.25	1.12	30.2	30.4	32.0
Nov-17-1999	3.9	<0.10	<0.10	2.08	0.37	0.45	28.4	34.8	31.6
Mar-01-2000	0.10	0.13	<0.10	0.23	0.37	0.14	26.2	21.5	20.3
Jun-07-2000									
Sep-27-2000	0.16	0.17	0.15	0.42	0.41	0.32	30.0	30.1	28.0
Nov-14-2000	<0.10	<.010	0.11	0.15	0.12	0.07	28.7	23.5	22.2
Mar-14-2001	0.19	0.23	0.40	0.33	0.28	0.59	25.5	24.8	29.3
Jun-04-2001	0.14	0.12	0.13	0.65	0.33	0.37	37.6	32.1	28.8
Aug-08-2001	0.16	0.19	0.16	0.46	0.43	0.41	30.0	26.5	32.1
Station D									
Mar-12-1996	NT	NT	NT	NT	NT	NT	NT	NT	NT
Apr-03-1996	<0.10	0.1	<0.10	0.5	0.5	0.5	23.9	25.2	23.7
Jun-27-1996	0.4	0.4	0.2	0.26	0.35	0.19	32.9	26.2	28.5
Sep-04-1996	0.2	0.2	0.2	0.22	0.20	0.20	25.8	27.0	26.5
Nov-13-1996	0.14	0.25	0.17	0.14	0.12	0.12	*	*	*
Mar-12-1997	0.46	0.27	0.76	0.28	0.17	0.28	*	*	*
Jun-09-1997	0.12	<0.10	0.16	0.07	0.06	0.11	21.0	21.0	25.0
Sep-11-1997	0.53	0.29	0.33	0.24	0.22	0.16	27.7	28.5	22.6
Nov-17-1997	0.72	0.24	0.24	0.54	0.09	0.14	30.4	25.8	18.8
Mar-03-1998	NT	NT	NT	NT	NT	NT	NT	NT	NT
Jun-03-1998	0.63	1.2	1.3	0.26	1.10	0.68	27.2	34.8	38.9
Sep-29-1998	0.64	0.47	0.50	0.29	0.27	0.21	34.6	27.7	26.5
Nov-10-1998	0.34	0.23	0.45	0.15	0.13	0.18	30.0	29.2	33.3
Feb-09-1999	0.29	0.40	0.38	0.18	0.27	0.51	26.6	28.0	32.6
Jun-18-1999	0.60	0.60	0.83	0.79	0.54	0.72	38.0	35.6	35.6
Sep-16-1999	0.68	0.53	0.81	0.44	0.51	0.85	36.7	35.0	39.8
Nov-17-1999	0.81	0.54	0.67	0.60	0.55	0.42	40.4	33.7	29.5
Mar-01-2000	0.71	0.83	0.34	0.41	1.10	0.19	33.6	31.2	19.8
Jun-07-2000	0.12	0.14	0.17	0.16	0.15	0.19	23.0	20.8	21.9
Sep-27-2000	0.39	0.22	0.35	0.18	0.13	0.22	37.0	25.8	23.5
Nov-14-2000	0.11	0.12	0.24	0.13	0.13	0.08	29.0	24.1	16.2
Mar-14-2001	0.21	0.23	0.23	0.06	0.09	0.06	18.2	19.8	20.2
Jun-04-2001	0.20	0.19	0.20	0.17	0.14	0.13	24.1	26.0	25.0
Aug-08-2001	0.26	0.19	0.14	0.14	0.12	0.09	24.5	18.0	20.5

Table 1 (cont). Sediment Monitoring Results

Sampling Date	Selenium Concentration			Organic Carbon			Percent Moisture		
	0-3 cm	3-8 cm	Whole Core	0-3 cm	3-8 cm	Whole Core	0-3 cm	3-8 cm	Whole Core
	ug/g, dry weight	ug/g, dry weight	ug/g, dry weight	%	%	%	%	%	%
Station E									
Mar-12-1996	NT	NT	NT	NT	NT	NT	NT	NT	NT
May-20-1996	0.1	0.1	0.1	0.7	1.0	0.7	41.1	35.8	34.5
Jun-27-1996									
Sep-04-1996	0.1	0.1	<0.1	1.08	0.45	0.40	37.9	32.7	30.9
Nov-13-1996	NT	NT	NT	NT	NT	NT	NT	NT	NT
Mar-13-1997	0.72	0.71	0.70	0.38	0.30	0.31	*	*	*
Jun-09-1997	0.82	1.0	1.0	0.12	0.16	0.06	*	*	*
Sep-11-1997	1.5	1.6	1.5	0.65	0.72	0.74	44.0	40.0	44.0
Nov-17-1997	1.6	1.3	1.9	0.69	0.52	0.78	42.0	34.2	45.8
Mar-03-1998	0.83	2.0	1.2	0.29	0.31	0.39	29.3	27.7	29.3
Jun-03-1998	NT	NT	NT	NT	NT	NT	NT	NT	NT
Sep-29-1998	NT	NT	NT	NT	NT	NT	NT	NT	NT
Nov-10-1998	0.24	0.18	0.25	0.16	0.18	0.21	31.6	26.7	26.8
Feb-10-1999	0.25	0.18	0.30	0.13	0.15	0.39	31.8	25.6	32.5
Jun-18-1999	0.32	0.48	0.78	0.32	0.54	0.45	37.4	38.0	43.5
Sep-17-1999	0.48	0.30	0.47	0.24	0.16	0.32	33.1	27.4	49.7
Nov-18-1999	0.96	0.54	0.20	0.44	0.24	0.08	44.0	29.9	8.2
Mar-02-2000	0.38	0.17	0.39	0.17	0.13	0.26	28.0	28.4	30.7
Jun-07-2000	0.19	0.13	0.23	0.32	0.13	0.23	36.0	36.2	27.1
Sep-27-2000	0.29	0.26	0.78	0.19	0.19	0.30	26.6	19.1	30.4
Nov-14-2000	0.54	0.46	0.93	0.20	0.23	0.51	33.4	29.3	29.4
Mar-14-2001	0.56	0.18	0.32	0.30	0.14	0.22	20.0	17.5	20.2
Jun-06-2001	0.68	0.54	0.36	0.40	0.07	0.11	29.6	26.2	27.0
Aug-08-2001	0.33	0.78	0.55	0.18	0.28	0.27	28.0	30.2	19.7
	0.36	0.47	0.59	0.14	0.24	0.24	20.2	21.7	25.1
Station F									
Mar-12-1996	NT	NT	NT	NT	NT	NT	NT	NT	NT
Jun-27-1996	0.6	0.5	0.2	0.69	0.58	0.18	41.9	33.3	28.9
Sep-05-1996	0.4	0.8	0.4	0.44	0.75	0.25	38.7	40.6	29.7
Nov-13-1996	0.24	0.40	0.25	0.05	0.16	0.05	*	*	*
Mar-13-1997	0.94	0.36	0.57	0.56	0.36	0.32	*	*	*
Jun-09-1997	0.12	0.14	0.35	0.08	0.12	0.26	26.0	20.0	29.0
Sep-12-1997	0.59	0.73	0.74	0.23	0.22	0.23	28.0	26.9	23.8
Nov-18-1997	1.3	1.9	1.4	1.16	1.43	1.12	47.3	46.9	44.6
Mar-04-1998	2.1	1.8	1.6	2.32	1.97	2.11	42.0	70.0	42.2
Jun-04-1998	0.66	1.0	1.3	0.49	0.59	1.48	34.8	31.2	50.7
Sep-29-1998	0.33	0.48	0.59	0.26	0.31	0.23	26.8	26.1	29.2
Nov-10-1998	0.28	0.55	0.70	0.21	0.26	0.33	26.7	33.7	29.0
Feb-10-1999	0.59	0.56	0.93	0.40	0.32	0.19	33.1	30.5	31.6
Jun-18-1999	0.37	0.52	0.70	0.22	0.27	0.37	29.8	26.3	28.5
Sep-17-1999	0.53	0.65	0.62	0.49	0.53	0.22	35.5	36.8	28.6
Nov-18-1999	0.27	0.25	0.42	0.33	0.24	0.26	36.5	28.9	29.3
Mar-02-2000	0.35	0.45	0.59	0.29	0.26	0.32	23.8	23.3	21.2
Jun-07-2000	0.30	0.37	0.52	0.24	0.24	0.35	27.9	24.6	20.5
Sep-27-2000	0.43	0.68	0.53	0.34	0.24	0.34	36.8	37.1	33.8
Nov-14-2000	0.22	0.39	0.52	0.18	0.25	0.20	25.6	25.2	27.0
Mar-14-2001	0.38	0.22	0.77	0.40	0.23	0.48	29.1	26.7	37.0
Jun-06-2001	0.66	0.44	0.73	0.21	0.22	0.27	27.4	24.5	25.3
Aug-08-2001	0.36	0.70	0.56	0.31	0.18	0.34	28.4	21.4	21.5

Table 1 (cont). Sediment Monitoring Results

Sampling Date	Selenium Concentration			Organic Carbon			Percent Moisture		
	0-3 cm	3-8 cm	Whole Core	0-3 cm	3-8 cm	Whole Core	0-3 cm	3-8 cm	Whole Core
	ug/g, dry weight	ug/g, dry weight	ug/g, dry weight	%	%	%	%	%	%
Station I									
Jun-13-1996	0.4	0.4	0.3	1.6	1.3	1.2	7.8	17.2	24.9
Mar-13-1997	1.5	0.8	0.4	1.76	0.79	0.56	*	*	*
Jun-03-1998	0.3	0.2	0.2	0.47	0.69	0.55	26.4	20.6	20.3
Jun-18-1999	4.8	4.5	4.4	1.90	1.89	1.96	16.1	25.1	25.9
Mar-01-2000	0.16	1.7	0.99	0.43	1.35	0.90	44.3	33.7	30.8
Jun-07-2000	4.4	2.2	1.7	1.92	1.55	1.39	4.6	20.9	20.1
Nov-14-2000	3.5	1.5	2.2	1.91	1.17	1.23	39.6	29.1	33.8
Mar-14-2001	0.81	1.3	1.6	0.80	1.16	1.01	28.3	30.5	33.3
Jun-06-2001	0.48	0.25	0.35	0.49	0.57	0.52	36.5	34.3	32.2
Aug-08-2001	0.34	0.32	0.21	0.26	0.28	0.14	22.9	24.1	25.0
San Luis Drain - Annual Survey									
30' South of Check 1 (1-2 C)									
Jun-10-1997	9.6	47	26	1.19	1.93	1.69	36.0	51.0	52.0
Jun-03-1998	22	9.7	29	1.49	1.49	1.55	49.7	44.8	44.9
Jun-16-1999	5.3	8.5	59	0.81	0.97	2.13	50.2	39.8	58.7
Jun-05-2000	14	15	15	1.33	1.55	1.11	54.0	53.6	40.1
Jun-05-2001	8.9	11	14	1.53	1.59	1.78	61.3	54.7	60.3
Midpoint of Checks 1 & 2 (1-2 B)									
Jun-10-1997	39	96	51	2.11	2.25	1.56	56.0	53.0	47.0
Jun-03-1998	64	68	8.3	1.53	1.71	1.31	56.3	52.7	55.4
Jun-16-1999	8.8	11	14	1.30	1.45	1.53	62.9	57.6	55.8
Jun-05-2000	9.4	8.4	18	1.35	1.27	1.46	65.9	59.6	57.1
Jun-05-2001	9.5	8.0	12	1.66	1.32	1.6	66.5	57.8	60.0
50' North of Check 2 (1-2 A)									
Jun-10-1997	NT	NT	NT	NT	NT	NT	NT	NT	NT
Jun-03-1998	15	NT	21	0.65	NT	0.97	42.6	NT	38.2
Jun-16-1999	19	64	71	1.99	2.68	2.27	35.5	49.0	54.9
Jun-05-2000	14	29	67	0.85	1.12	1.66	25.0	32.2	44.1
Jun-05-2001	18	71	48	1.05	1.9	1.92	19.7	43.6	43.2
50' South of Check 10 (10-11 C)									
Jun-10-1997	7.2	15	31	1.28	1.34	2.67	50.0	57.0	42.0
Jun-04-1998	21	39	17	0.72	1.66	1.43	44.0	62.6	56.4
Jun-16-1999	19	75	16	0.93	2.07	1.34	43.8	61.5	52.8
Jun-05-2000	47	84	41	1.23	1.65	1.85	49.6	57.1	60.9
Jun-05-2001	39	140	33	1.32	3.05	1.74	36.0	65.5	52.0
Midpoint of Checks 10 & 11 (10-11 B)									
Jun-10-1997	11	12	NT	1.57	1.16	NT	59.0	48.0	NT
Jun-04-1998	7.5	8.7	17	0.91	0.93	1.43	54.0	45.1	72.6
Jun-16-1999	26	8.4	6.0	1.24	0.89	0.56	51.5	52.8	39.4
Jun-05-2000	7.5	22	5.8	1.28	0.99	0.93	61.4	52.8	53.2
Jun-05-2001	10	14	10	1.40	1.86	1.43	54.1	60.7	61.8
50' North of Check 11 (10-11 A)									
Jun-10-1997	24	43	39	1.41	1.97	1.83	48.0	57.0	53.0
Jun-04-1998	18	55	50	1.14	2.57	1.68	47.2	61.2	53.5
Jun-16-1999	14	26	45	0.61	1.82	1.56	34.7	47.1	53.1
Jun-05-2000	12	58	51	0.66	2.55	1.69	32.1	64.4	54.1
Jun-05-2001	16	64	50	1.25	2.51	2.31	36.3	59.8	50.4

Table 1 (cont). Sediment Monitoring Results

Sampling Date	Selenium Concentration			Organic Carbon			Percent Moisture		
	0-3 cm	3-8 cm	Whole Core	0-3 cm	3-8 cm	Whole Core	0-3 cm	3-8 cm	Whole Core
	ug/g, dry weight	ug/g, dry weight	ug/g, dry weight	%	%	%	%	%	%
50' South of Check 14 (14-15 C)									
Jun-11-1997	7.1	34	8.0	1.54	2.62	1.93	63.0	70.0	63.0
Jun-04-1998	31	11	42	0.85	1.96	1.11	45.2	67.4	42.3
Jun-16-1999	4.0	11	13	1.00	1.87	1.30	60.3	63.6	62.0
Jun-05-2000	5.3	4.8	45	1.34	1.36	2.41	60.6	41.0	63.1
Jun-05-2001	4.9	4.8	14	1.11	1.17	2.66	52.1	51.3	62.5
Midpoint of Checks 14 & 15 (14-15 B)									
Jun-11-1997	2.9	22	10	0.38	1.11	1.91	29.0	49.0	56.0
Jun-04-1998	3.4	3.4	5.7	1.04	1.08	1.17	55.2	54.9	58.0
Jun-17-1999	3.0	3.1	3.0	0.95	0.96	0.94	58.0	56.0	52.6
Jun-06-2000	3.3	4.1	3.1	1.03	0.99	0.93	56.0	52.5	53.3
Jun-05-2001	5.1	4.7	5.1	1.24	1.15	1.19	61.5	56.8	57.6
50' North of Check 15 (14-15 A)									
Jun-11-1997	40	48	3.8	2.37	2.83	0.59	63.0	67.0	63.0
Jun-04-1998	29	47	59	1.46	2.87	3.21	51.8	65.5	68.7
Jun-17-1999	43	76	76	3.64	3.23	2.84	61.9	65.2	63.5
Jun-06-2000	23	76	55	0.79	2.42	2.32	35.3	53.5	53.0
Jun-05-2001	43	76	62	2.13	2.93	2.37	37.4	62.2	56.9
Midpoint of Checks 17 & 18 (17-18 B)									
Jun-10-1997	2.7	3.5	3.8	0.67	0.80	1.82	46.0	45.0	66.0
Jun-03-1998	2.0	2.8	2.7	0.57	0.83	0.90	24.8	34.1	44.9
Jun-17-1999	2.3	1.6	1.6	0.59	0.71	0.52	45.5	37.9	40.3
Jun-06-2000	2.2	2.0	1.9	0.76	0.66	0.59	36.3	38.9	38.9
Jun-06-2001	1.8	2.0	2.1	0.47	0.60	0.54	34.3	35.6	39.6
50' North of Check 18 (17-18 A)									
Jun-10-1997	48	66	100	2.37	1.92	2.98	57.0	54.0	60.0
Jun-03-1998	35	65	75	1.25	2.39	2.33	38.0	53.8	57.4
Jun-17-1999	38	100	87	1.11	5.19	3.16	47.6	62.2	61.6
Jun-06-2000	26	49	43	0.81	1.84	1.54	35.6	47.9	45.7
Jun-06-2001	11	32	50	0.96	2.10	1.96	40.7	58.8	46.7

NT = Not Tested   * = Lost Data

Reporting Limit: Selenium, 0.01 ug/g
Significant Digits: Selenium, 2   Organic Carbon, 2 or 3   Percent Moisture, 2 or 3

Laboratory: March 1996 to September 1996 USBR Laboratory / Sacramento
October 1996 to Present USGS Laboratory / Denver

Table 2. Sediment Monitoring to Measure Laboratory Precision (Duplicates)

Station	Sample Type	Sampling Date	Original ug/g	Re-sample ug/g	Quality Control Duplicate ug/g	Re-sample ug/g	RPD Per Cent
Water Year 1997							
B	3-8 cm	Nov-12-1996	41	43	26	28	44.8
E	3-8 cm	Mar-13-1997	1.0		0.96		4.1
B	whole	Mar-13-1997	42		41		2.4
C	3-8 cm	Jun-09-1997	0.20		0.20		0.0
B	3-8 cm	Jun-10-1997	27	31	18	19	40.0
A	3-8 cm	Jun-10-1997	4.2		4.3		2.4
1-2 B	whole	Jun-10-1997	51		54		5.7
10-11 C	0-3 cm	Jun-10-1997	7.2		7.2		0.0
14-15 B	3-8 cm	Jun-11-1997	22		21		4.7
17-18 A	whole	Jun-10-1997	100		86		15.1
B	whole	Sep-11-1997	48		43		11.0
A	whole	Sep-11-1997	50	48	21	23	81.7
Water Year 1998							
C	3-8 cm	Nov-17-1997	0.10		0.10		0.0
E	0-3 cm	Nov-17-1997	0.83		0.89		7.0
B	3-8 cm	Mar-03-1998	41		40		2.5
A	whole	Jun-04-1998	7.0		6.6		5.9
D	3-8 cm	Jun-03-1998	1.2		1.1		8.7
17-18 A	whole	Jun-04-1998	75		79		5.2
1-2 B	3-8 cm	Jun-03-1998	68		76		11.1
10-11 C	3-8 cm	Jun-04-1998	39		39		0.0
10-11 A	0-3 cm	Jun-04-1998	18		22		20.0
A	3-8 cm	Sep-28-1998	23		23		0.0
E	whole	Sep-29-1998	0.25		0.25		0.0
Water Year 1999							
B	0-3 cm	Nov-09-1998	17		17		0.0
A	whole	Nov-10-1998	31		30		3.3
B	3-8 cm	Feb-09-1999	31		30		3.3
E	whole	Feb-10-1999	0.78		0.86		9.8
A	whole	Feb-10-1999	11		11		0.0
A	whole	Jun-17-1999	23	21	14	13	48.6
I	3-8 cm	Jun-18-1999	4.5		4.4		2.2
B	3-8 cm	Jun-18-1999	27		28		3.6
1-2 B	3-8 cm	Jun-16-1999	11		11		0.0
10-11 C	whole	Jun-16-1999	16		18		11.8
14-15 B	3-8 cm	Jun-17-1999	3.1		4.2		30.1
B	3-8 cm	Sep-16-1999	29		30		3.4
A	whole	Sep-17-1999	30		29		3.4
Water Year 2000							
B	whole	Nov-17-1999	39	44	14	16	94.3
A	whole	Nov-18-1999	4.3		3.8		12.3
I	whole	Mar-01-2000	0.99		0.97		2.0
B	whole	Mar-01-2000	29		30		3.4
A	whole	Mar-02-2000	2.4		2.4		0.0
I	3-8 cm	Jun-07-2000	2.2		2.3		4.4
D	whole	Jun-07-2000	0.17		0.15		12.5
1-2 C	whole	Jun-05-2000	15		14		6.9
10-11 C	whole	Jun-05-2000	41		41		0.0
10-11 A	whole	Jun-05-2000	51		49		4.0
17-18 B	3-8 cm	Jun-06-2000	2.0		2.0		0.0
A	whole	Sep-27-2000	70	65	120	111	52.6
D	whole	Sep-27-2000	0.35		0.36		2.8
Water Year 2001							
A	whole	Nov-14-2000	10		10		0.0
D	whole	Nov-14-2000	0.24		0.20		18.2
B	whole	Mar-07-2001	110		130		16.7
D	whole	Mar-14-2001	0.23		0.21		9.1
F	whole	Mar-14-2001	0.77		0.51		40.6
D	whole	Jun-04-2001	0.21	0.20	1.5	0.20	150.9
1/2 B	whole	Jun-05-2001	12		12		0.0
10/11 A	whole	Jun-05-2001	50		50		0.0
14/15 B	whole	Jun-05-2001	5.1		5.1		0.0
I	whole	Aug-08-2001	0.21		0.24		13.3
C	whole	Aug-08-2001	0.16		0.14		13.3

Table 3. Sediment Monitoring to Measure Repeatability (Replicates)

Station	Sample Type	Sampling Date	Original ug/g	Replicate ug/g	Absolute Difference ug/g	RPD Per Cent
Water Year 1997						
A	0-3 cm	Jun-10-1997	48	30	18	46.2
A	3-8 cm	Jun-10-1997	66	53	13	21.8
A	whole	Jun-10-1997	100	77	23	26.0
Water Year 1998						
14-15 C	0-3 cm	Jun-04-1998	31	14	17	75.6
14-15 C	3-8 cm	Jun-04-1998	11	19	8	53.3
14-15 C	whole	Jun-04-1998	42	24	18	54.5
Water Year 1999						
A	0-3 cm	Jun-17-1999	2.5	3.1	0.6	21.4
A	3-8 cm	Jun-17-1999	2.7	3.0	0.3	10.5
A	whole	Jun-17-1999	23	4.2	18.8	138.2
1-2 C	0-3 cm	Jun-16-1999	5.3	7.6	2.3	35.7
1-2 C	3-8 cm	Jun-16-1999	8.5	10	1.5	16.2
1-2 C	whole	Jun-16-1999	59	29	30	68.2
Water Year 2000						
A	0-3 cm	Jun-06-2000	2.6	2.5	0.1	3.9
A	3-8 cm	Jun-06-2000	2.8	3.1	0.3	10.2
A	whole	Jun-06-2000	3.0	4.2	1.2	33.3
14-15 C	0-3 cm	Jun-06-2000	5.3	4.0	1.3	28.0
14-15 C	3-8 cm	Jun-06-2000	4.8	5.3	0.5	9.9
14-15 C	whole	Jun-06-2000	4.5	7.8	3.3	53.7

GRASSLAND BYPASS PROJECT

10

Sediment Quantity in the San Luis Drain

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Grassland Area Farmers

The purpose of this aspect of the Grassland Bypass Project Monitoring Program (Monitoring Program) is to determine the changes in quantity and movement of sediment in the San Luis Drain (SLD). This is accomplished by actual measurement of the bed sediment and using total suspended solids measurements at the inlet and outlet of the SLD.

Sediment Quantity Monitoring Performed by the San Luis and Delta-Mendota Water Authority

Section 11.4 of the Compliance Monitoring Program Phase II (USBR et al., 2001) describes the procedure to measure the quantity of sediment in the SLD. The 2001 Monitoring Program procedure for sediment quantity measurement is somewhat different from the Phase I Monitoring Program (USBR et al., 1996). The revised procedure requires two sediment depth measurement at each location; one on either side of the SLD. These two measurement are used establish an average depth of sediment above SLD invert so that the volume of total sediment may be estimated.

The Monitoring Program calls for the measurement of sediment in four reaches of the SLD (Reaches 1, 10, 14, and 17). Measurements of sediment depths were to be made using the Monitoring Program protocol. The locations of the sediment measurement points duplicated those of the March of 1987 survey performed by Summers Engineering. The Monitoring Program calls for measurements to be made once per year.

The sediment in the SLD was measured in all 19 reaches of the Grassland Bypass Project (GBP) which included the four required reaches. Measurements were made in accordance with the Monitoring Program. The results are reported by reach in comparison to the March 1987, 1997, 1998, 1999, and 2000 surveys.

Table 1 summarizes the results. The results are also shown graphically in Figure 1. The results indicate that there is a net increase of 21,400 cubic yards from August 2000 to November 2001, compared to a net increase of 25,700 cubic yards from July 1999 to August 2000. A total of 75,200 cubic yards of sediment has accumulated in the SLD since 1997.

Survey measurements indicated that individual reaches of the SLD gained a maximum of 6,400 cubic yards (Pool 16), and lost a maximum of 300 cubic yards (Pool 12) as compared to the 2000 sediment survey. The average depth of sediment throughout the SLD was 2.3 feet, with a maximum depth of 6.4 feet measured in Pool 15.

In general, sediment accumulation is occurring in the first 5 reaches (Pools 18 to 14), as the suspended solids drop out of the water column upon entering the SLD. The water velocity within the SLD is kept below 1 foot per second to prevent the suspension of material from the sediment bed. The slower velocity also increases the rate at which suspended solids drop out of the water column.

Table 1. 2001 San Luis Drain Sediment Survey
Survey Summary and Comparison

Pool	Checks	Distance (miles)	March 1987 Volume (cu yd)	March 1987 Vol / mile (cu yd/mi)	June-Sept. 1997 Volume (cu yd)	June-Sept. 1997 Vol / mile (cu yd/mi)	July 1998 Volume (cu yd)	July 1998 Vol / mile (cu yd/mi)	July 1999 Volume (cu yd)	July 1999 Vol / mile (cu yd/mi)	August 2000 Volume (cu yd)	August 2000 Vol / mile (cu yd/mi)	November 2001 Volume (cu yd)	November 2001 Vol / mile (cu yd/mi)
End	End to 1	2.64	3,176	1,203	1,697	643	2,795	1,059	3,602	1,364	4,451	1,686	5,611	2,125
1*	1 to 2	1.82	2,567	1,410	1,840	1,011	3,375	1,854	4,514	2,480	5,306	2,915	5,487	3,015
2	2 to 3	0.28	1,059	3,781	531	1,896	955	3,411	872	3,114	836	2,986	1,748	6,242
3	3 to 4	2.57	4,909	1,910	3,350	1,304	4,839	1,883	3,244	1,262	5,582	2,172	6,404	2,492
4	4 to 5	1.8	4,440	2,467	6,521	3,623	9,049	5,027	6,760	3,756	8,968	4,982	9,836	5,465
5	5 to 6	2.06	4,242	2,059	4,370	2,121	4,596	2,231	4,139	2,009	5,679	2,757	6,481	3,146
6	6 to 7	0.83	2,160	2,602	2,584	3,113	2,432	2,930	1,762	2,123	2,416	2,910	2,321	2,797
7	7 to 8	0.45	3,935	8,744	3,278	7,285	3,135	6,967	3,099	6,887	3,068	6,817	2,842	6,315
8	8 to 9	0.47	907	1,931	816	1,736	778	1,655	627	1,334	1,420	3,022	1,600	3,404
9	9 to 10	3.2	6,963	2,176	6,390	1,997	8,571	2,678	4,632	1,448	8,797	2,749	9,364	2,926
10*	10 to 11	1.46	2,647	1,813	2,708	1,855	2,781	1,905	3,101	2,124	3,669	2,513	3,835	2,626
11	11 to 12	2.5	4,835	1,934	4,947	1,979	7,620	3,048	6,499	2,600	10,194	4,078	10,900	4,360
12	12 to 13	0.46	784	1,705	909	1,977	1,504	3,270	629	1,367	2,274	4,942	1,966	4,273
13	13 to 14	0.91	2,038	2,240	1,771	1,946	2,657	2,920	2,709	2,977	3,835	4,215	4,378	4,811
14*	14 to 15	1.34	2,304	1,719	3,803	2,838	5,427	4,050	12,030	8,978	11,466	8,557	14,917	11,132
15	15 to 16	0.96	1,822	1,898	2,700	2,813	6,456	6,725	11,699	12,186	15,420	16,062	18,661	19,438
16	16 to 17	1.68	5,863	3,490	7,605	4,527	10,482	6,239	12,895	7,676	14,691	8,745	21,132	12,578
17*	17 to 18	0.68	1,885	2,772	3,006	4,420	2,435	3,581	3,205	4,713	3,477	5,113	4,900	7,206
18	18 to 19	0.97	1,558	1,607	1,768	1,822	2,519	2,597	2,603	2,684	2,819	2,906	3,427	3,533
Totals		27.08	58,094		60,594		82,406		88,621		114,368		135,809	
Averages				2,145		2,238		3,370		3,741		4,744		5,678

* Required by Grassland Bypass Monitoring Program

Total Suspended Solids Measurements

The Monitoring Program calls for total suspended solids (TSS) measurements as part of the water quality monitoring. These measurements were to be taken just downstream of the inlet to the SLD (Site A) and just upstream of the outlet (Site B). Measurements were taken on a weekly basis at these sites. The monthly average data are shown for WY 1997 to WY 2001 in Table 2. Overall, the WY 2001 data show that TSS concentrations at Site A are higher than at Site B by a factor of 2.3, averaged over the water year. One commitment of the GBP was to minimize flows so as to not cause sediment movement or suspension of sediments from the bottom of the SLD. The data suggest that the suspended sediments are settling in the SLD and that there is no net movement or suspension of sediments.

References

U.S. Bureau of Reclamation et al. 2001. Compliance Monitoring Program for Use and Operation of the Grassland Bypass Project, Phase II, March 2002. U.S. Bureau of Reclamation, Mid-Pacific Region, Sacramento, CA.

U.S. Bureau of Reclamation et al. 1996. Compliance Monitoring Program for Use and Operation of the Grassland Bypass Project, September 1996. U.S. Bureau of Reclamation, Mid-Pacific Region, Sacramento, CA.

Figure 1. San Luis Drain Sediment Survey Comparison

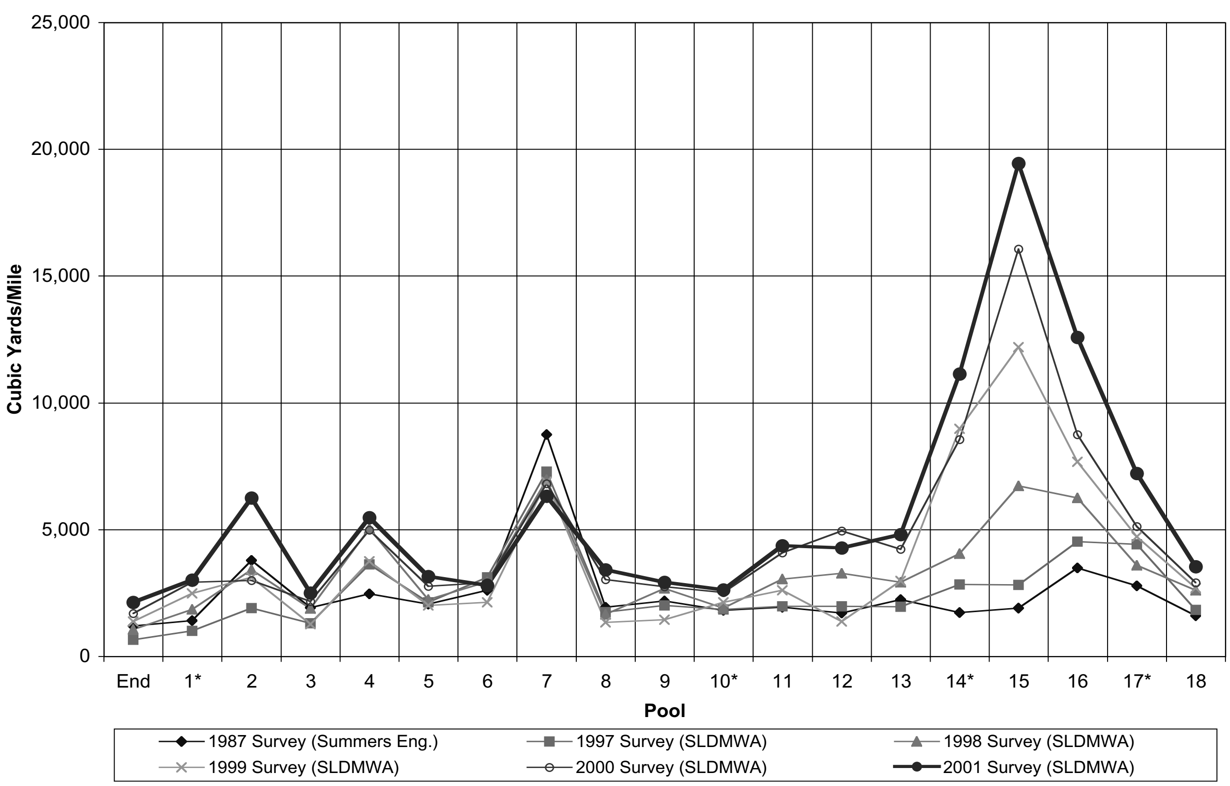

Table 2. Total Suspended Solids

Date	Site A TSS mg/L (Monthly Average)	Site B TSS mg/L (Monthly Average)
Oct. 1996	92	38
Nov. 1996	59	8
Dec. 1996	77	19
Jan. 1997	135	23
Feb. 1997	57	31
Mar. 1997	94	33
Apr. 1997	111	38
May 1997	101	56
Jun. 1997	107	27
Jul. 1997	136	21
Aug. 1997	140	22
Sept. 1997	111	22
WY 1997 Average	102	28
Oct. 1997	51	24
Nov. 1997	86	19
Dec. 1997	45	36
Jan. 1998	61	24
Feb. 1998	243	143
Mar. 1998	290	114
Apr. 1998	200	69
May 1998	270	86
Jun. 1998	123	42
Jul. 1998	171	49
Aug. 1998	94	44
Sept. 1998	37	33
WY 1998 Average	139	57
Oct. 1998	43	61
Nov. 1998	28	40
Dec. 1998	19	30
Jan. 1999	54	19
Feb. 1999	149	50
Mar. 1999	57	33
Apr. 1999	43	38
May 1999	97	60
Jun. 1999	160	68
Jul. 1999	145	65
Aug. 1999	166	61
Sept. 1999	69	71
WY 1999 Average	86	49

Date	Site A TSS mg/L (Monthly Average)	Site B TSS mg/L (Monthly Average)
Oct. 1999	73	57
Nov. 1999	62	43
Dec. 1999	26	51
Jan. 2000	67	64
Feb. 2000	250	71
Mar. 2000	148	57
Apr. 2000	134	69
May 2000	165	45
Jun. 2000	136	63
Jul. 2000	99	53
Aug. 2000	120	58
Sept. 2000	59	57
WY 2000 Average	111	57
Oct. 2000	63	51
Nov. 2000	36	44
Dec. 2000	46	46
Jan. 2001	49	40
Feb. 2001	108	33
Mar. 2001	84	41
Apr. 2001	67	42
May 2001	188	46
Jun. 2001	184	42
Jul. 2001	142	41
Aug.20 01	116	44
Sept. 2001	65	32
WY 2001 Average	96	42

GRASSLAND BYPASS PROJECT

11

Quality Control

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Data Quality Objectives

The Data Collection and Reporting Team (DCRT) uses the laboratory data from this project to support the determination of whether Selenium (Se) levels in the Grassland Bypass exceed regulatory compliance levels. Because individuals use the data generated by this program for regulatory compliance and baseline monitoring purposes, the data must be of the highest degree of reliability. Sample collection from different environmental media and analytical methods performed by the laboratories must adhere to the guidelines established in the quality assurance project plan (QAPP).

Quality Assurance Project Plan

The QAPP defines the data quality objectives (DQOs) for the Monitoring Program, and each agency has established DQOs for their environmental measurements. The QAPP addresses both quantitative goals, including precision, accuracy, and completeness, and qualitative goals, including representativeness and comparability.

The QAPP includes all the requirements identified in the August 1994 Draft Interim Final, "U.S. EPA Requirements for Quality Assurance Project Plans for Environmental Data Operations", EPA QA/R-5. It describes quality assurance/quality control (QA/QC) protocol associated with each agency's sample collection and laboratory activities; provides acceptance criteria for data validation procedures; and describes corrective actions to be taken when data fail to meet such criteria. The DCRT tailored the QAPP specifically to provide the necessary protocol for the documentation of QA/QC activities.

Quality Assurance Oversight

QA/QC oversight for the Monitoring Program is the responsibility of the U.S. Bureau of Reclamation (USBR). A QA/QC oversight manager (QAQCOM) serving in a cooperative capacity ensures the implementation of commitments, guidelines, practices, and protocols outlined in the QAPP in compliance with the goals and objectives of the project. The QA staff of the USBR's Mid Pacific Region located in Sacramento, CA carries out this oversight role. They use guidelines, protocols, and criteria established in the QAPP to monitor and validate data collected by USBR personnel and to assess the data collection and validation processes used by the other participating agencies. When USBR identifies a noncompliance QA issue, they notify the appropriate QA Officer, and the agency implements corrective actions to resolve the problem. USBR brings any unresolved issues between the QAQCOM and a participating agency's QA Officer to the attention of the Data Collection and Reporting Team (DCRT) for resolution.

As part of the QA oversight responsibility, USBR conducts audits of all participating environmental laboratories and reviews the data collection activities of the participating agencies for adherence to protocol.

Sampling groups participating in the Monitoring Program conduct system audits of one another's protocols by reviewing the sampling method in the field. For example, CDFG conducted a system audit of USFWS's sampling group and vice versa.

Quality Assurance Accomplishments

Laboratory Performance and System Audits

USBR's QA staff conducted performance and system audits of the following laboratories:

Laboratory / Location	Date(s)	Analysis Type
Trace Substance Laboratory in Rolla, Missouri	April 30 & May 1, 1996	Tissue Analysis
Severn Trent Services Laboratory in West Sacramento, California	October 10, 1996; July 10 & 11, 2001	Water Analysis
U.S. Geological Survey' s Geological Division Laboratory in Denver, Colorado	December 2 & 3, 1998; July 17 & 18, 2001	Sediment Analysis
Twining Laboratory in Fresno, CA	June 22 & 23, 1999	Water Analysis
South Dakota State University Laboratory in Brookings, South Dakota	September 23, 1999	Water Analysis
Water Pollution Control Laboratory in Rancho Cordova, California	January 13 & 14, 2000	Tissue Analysis
Weck Laboratories in City of Industry, California	August 10 & 11, 2000	Water Analysis
BES Laboratory in Pleasant Hill, California	September 28, 2000	Toxicity Analysis

During 2001, the QA staff was able to audit the Severn Trent Services Laboratory and the U.S Geological Survey's Geological Division Laboratory. The audit process involves an initial demonstration of performance using external quality assurance samples followed by a review of the latest version of the laboratory's QA Manual, the laboratory's performance study results for the past three years, and the laboratory's most recent internal or external audit report with corrective actions. Once the laboratory has demonstrated good performance and passed the initial document review process, the QA staff will conduct an on-site system audit. During the on-site system audit, the USBR QA staff reviews all of the detailed aspects of the quality system to ensure laboratory personnel understand and adhere to the protocols cited in the laboratory QA manual. The auditors then send an audit report which addresses all of the deficiencies identified during the system audit to the laboratory with a recommended time frame for the laboratory to respond, implement and document the corrective actions. The following tables are examples of how USBR summarized and documented performance sample results for the Severn Trent Services Laboratory and the U.S Geological Survey's Geological Division Laboratory (Table 1 and 2).

The two laboratories audited by the USBR QA staff in 2001 performed well on the system audit. Where USBR observed deficiencies during the on-site system audit, the laboratories have incorporated our recommendations or are in the process of implementing them.

Sample Collection System Audits

Participating agencies performed sample collection system audits on each other during 1997, and 1998. Since the methodology did not change, participating agencies did not conduct field audits on each other during 2001. During the annual sediment monitoring of the San Luis Drain for the Grassland Bypass Program on June 5th and 6th in 2001, USBR QA staff conducted a field audit of USBR's Mid Pacific Region Environmental Monitoring Team (EMT). The field audit focused on the quality of the environmental samples collected by the EMT and the ability of the EMT to adequately support and document the sample collection process. The purpose of the field audit was to identify and prevent problems in the field which could compromise sample integrity. Even though the field audit of the EMT found some deficiencies and deviations from stated protocols, overall the USBR QA staff found EMT members to be very knowledgeable and skilled in collecting environmental sediment samples for the Grassland Bypass Project. Since the field audit, the EMT has remedied all deficiencies and deviations from stated protocols.

Data Validation Activities

The following routine data validation activities were performed to ensure data reliability as stated in the QAPP:

Type of data & field logbooks	Validation Group
Sediment data from USBR	USBR QA staff
Water data from CVRWQCB	USBR QA staff
Biota data from USFWS	USBR QA staff
Toxicity data from BES	USBR QA staff
Field logbooks from USBR's sampling group	USBR QA staff

Table 1. Severn Trent Services Laboratory Performance Study
EPA Method 300.0A Sample ID QA463;
Date Completed: 06/25/00 Matrix = Water mg/L

Parameter	Result	True Value	% Recovery	Acceptance Limit
Sulfate	1200	1180	102	80 - 120

Table 2. U.S Geological Survey Laboratory Performance Study
Date completed: 8/20/01 Matrix = Soil mg/Kg

Sample ID	Parameter	Result	True Value	% recovery	Acceptance Limit
QA450	Selenium	79	79.6	99	80 - 120
QA451	Total Org. Carbon	8200	8500	96	80 - 120

Data Validation Methods

The QAQCOM is responsible for ensuring the participating agencies properly validate their analytical results, identify problems with their analytical data, and contact their respective laboratories to initiate corrective actions. To accomplish these tasks, USBR QA staff routinely reviews and validates the data produced by the participating agencies.

USBR QA staff assesses the validity of the analytical results by comparing QC results to acceptance criteria identified in Table 9 of the QAPP. The guidelines address both internal and external QC sample results. The QAPP defines internal QC samples as those check samples incorporated by the laboratories performing the work and defines external QC samples as those check samples submitted to the laboratories by the contracting agency. USBR QA staff ensures agencies are incorporating correct numbers and types of external QC samples into each batch of field samples during the data validation process and addresses any nonconformance issues with the agencies directly. Another assessment activity performed by the QA staff is to make sure participating agencies spike their external QC check samples at concentrations near historical levels as a means of ensuring better sample accuracy.

As part of this data validation process, USBR brings laboratory QC summary report problems to the attention of the each agency's QA officer. The QA Officers then address these problems with the laboratories. For example, QA Officers may request laboratories take proper corrective actions on internal QC check sample results outside of established control limits. USBR also checks data packages to ensure laboratories document details of their corrective actions in the case narrative section or as footnotes in the QC summary section.

Reviewing data packages to identify possible outliers is another part of the validation process. Once USBR QA staff identifies a data point as a possible outlier, they promptly request the laboratory re-analyze the sample. For example, USBR QA staff identified the sediment sample selenium result of 110 ug/g for monitoring Site B collected on March 7, 2001 as a potential outlier. Project field personnel sampled this site seventeen times from June 1996 through March 2001 with the following selenium results: 30, 20, 40, 42, 0.11, 48, 41, 45, 26, 17, 23, 31, 26, 39, 29, 19, and 110 ug/g respectively for the whole core sample as shown in Table 3. Upon re-analyzing the sample demonstrating the 110 ug/g selenium result, the laboratory confirmed the original result (Table 3). USBR QA staff followed the same evaluation process to determine data result 0.1 ug/g as another potential outlier. Although confirmed potential outlier measurements will remain in the database, periodically USBR QA staff reassesses them as the laboratory generates additional data points for the site by conducting a statistical trend analyses study. Once a data point is statistically proven to be an outlier, USBR QA staff will either flag the data point as a questionable measurement or they will remove the data point from the database entirely.

As a means of assessing both laboratory performance and field sampling homogenization techniques, USBR collected four duplicate sediment samples from the San Luis Drain, one duplicate sediment sample from Mud Slough, and one duplicate sediment sample from Salt Slough and submitted them to the U.S. Geological Survey, Denver Laboratory for selenium analyses. These duplicate sample results (Table 4) provided information on both laboratory performance (precision) and ability of field personnel to properly homogenize samples. USBR QA staff then determined if the results met their established acceptance level. The USBR QA team concluded the values in Table 4 demonstrated acceptable analytical precision by the laboratory and sample homogenization techniques by USBR's field sampling team.

Even though the final duplicate results in Table 4 demonstrate excellent precision, this was not the case when the data report initially came back from the laboratory. The original duplicate results for Site D (whole) differed excessively from each other (0.21 ug/g, 1.5 ug/g). As a result, the USBR QA staff had to determine if the field samplers failed to properly homogenize the duplicate samples or if the laboratory failed to demonstrate acceptable analytical precision upon analyzing these duplicate samples. Upon re-analyzing the duplicate samples for Site D (whole), the laboratory was unable to confirm the initial 1.5 ug/g selenium result for one of the duplicate samples. Based on the laboratory's inability to confirm the original selenium result for one of the duplicate samples, USBR's QA staff concluded the laboratory initially failed to demonstrate acceptable analytical precision for the Site D (whole) duplicate samples. Only after re-analyzing a bracket of samples which included the duplicate samples for Site D (whole) was the laboratory able to demonstrate the excellent

Table 3
GRASSLAND BYPASS PROGRAM
SAN LUIS DRAIN SEDIMENT MONITORING
SELENIUM LEVELS (ug/g, dry weight)

Site B	Whole Core	Re-analyzed Result	Relative % Difference Level	Confirmation Acceptance
June 27, 1996	30	–	–	–
September 04, 1996	20	–	–	–
November 12, 1996	40	–	–	–
March 13, 1997	42	–	–	–
June 10, 1997	0.11	0.18	0.07	± 2RL
September 11, 1997	48	–	–	–
November 18, 1997	41	–	–	–
March 03, 1998	45	–	–	–
June 03, 1998	26	–	–	–
November 09, 1998	17	–	–	–
February 09, 1999	23	–	–	–
June 18, 1999	31	–	–	–
September 16, 1999	26	–	–	–
November 17, 1999	39	–	–	–
March 01, 2000	29	–	–	–
September 27, 2000	19	–	–	–
March 07, 2001	110	100	9.5	≤ 35%

Table 4
QUALITY ASSURANCE RESULTS
GBP SEDIMENT MONITORING PROGRAM
CONDUCTED JUNE 04-06, 2001
DUPLICATES TO MEASURE LABORATORY PRECISION

Site Location	Selenium Levels	Relative Percent Difference (RPD) or Difference	Duplicate Acceptance Criteria
Site D (whole)	0.20 / 0.20 ug/g	0.00	± 2RL
SLD 1/2B (whole)	12 / 12 ug/g	0.0%	≤ 35%
SLD 10/11A (whole)	50 / 50 ug/g	0.0%	≤ 35%
SLD 14/15B (whole)	5.1 / 5.1 ug/g	0.0%	≤ 35%
SLD 17/18A (whole)	50 / 51 ug/g	2.0%	≤ 35%
Site F (whole)	0.73 / 0.71 ug/g	2.8%	≤ 35%

precision for the Site D (whole) duplicate samples in Table 4.

USBR QA staff reviews all field calibration sheets obtained from each agency performing field sampling for documentation of routine instrument calibrations to ensure reliable field measurements for this project.

QA Issues of Concern

USBR QA staff found all the agencies adhered to the protocols outlined in the QAPP.

Uncertainty Associated with Environmental Measurements

As with all quantitative measurements, there is a degree of uncertainty associated with the values provided. This is especially true for environmental data where measurement error may be introduced in the sample collection phase as well as in the laboratory service phase. Program participants and the public need to understand that values presented in laboratory reports are not absolute, but rather represent values with associated precision and accuracy uncertainties as defined in Table 9 of the QAPP. In addition, as the concentration of the parameter approaches the limit of detection for the particular analytical method, the level of uncertainty of the result increases significantly as shown in Figure 4 of the QAPP. The data user needs to understand the degree of uncertainty or the confidence limits associated with the data.

Summary

During WY 2001, the participating agencies in the Monitoring Program complied with the protocols outlined in the QAPP. Adherence to the QAPP ensured the reliability of the data collected and provided the necessary documentation to support the validity of the measurements. Where exceptions did occur, USBR's QA staff was able to quickly identify and address the issues, thereby ensuring the data quality objectives of the program.

During 2001, the USBR QA staff conducted thorough audits of two program laboratories and their own EMT, and continually performed routine review and validation of the data collected throughout the year. When using the data to make decisions, individuals need to know the analytical uncertainty associated with the data. In order to perform QA oversight duties, USBR requires full cooperation from the participating agencies. In performing QA oversight, USBR serves to remind agencies of the need to adhere to protocols established in the QAPP.